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ON THE SEVERAL EFFICIENCIES OF THE STEAM ENGINE, AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

By ROBERT H. THURSTON.

Presented to the American Society of Mechanical Engineers, Philadelphia Meeting, April, 1882.

SECTION II.—APPLICATIONS AND DEDUCTIONS.

11. Method of Construction of the Diagram of Efficiencies.

By the application of this method, as proposed by the writer, we may thus determine, from the results of experiment, a set of data and a graphical representation of those results which may serve as a standard for the class to which the engine examined belongs.

It is further evident that, the ratio of expansion at maximum efficiency being determined by experiment, and with precision by this graphical method, it becomes easy to ascertain with exactness the value of the ratio of expansion at maximum commercial economy.

The base line, *VL*, for maximum efficiency of engine being fixed, the position of the point *V* on that line is readily obtained, and thus the line *VZ* becomes known, and the ratio of expansion at maximum commercial economy is determined. Similarly, by extending the line *VL* until it becomes proportional to the sum of all costs, constant and

variable, the ratio of expansion giving maximum work per dollar expended with the given engine, may, if desired, be found.

The accompanying plate represents a series of real Curves of Efficiency, several of which are given by working engines. Such curves are here, for the first time, presented.

The straight line $A_1 A$, for the case in which $[n = (-1)]$ is the line of Constant Efficiency obtained in an assumed case of no gain and no variation of efficiency with increasing expansion from $r = o$ to $r = \infty$.

The curve marked G, and dotted, is the standard Curve of Efficiency for adiabatic expansion of steam containing initially ten per cent. water ($n = 1{\cdot}125$).

The line F is the Curve of Mean Pressure or of Efficiency for steam initially dry ($n = 1{\cdot}135$).

The other curves are all obtained by reference to experiments on various classes of engines. B is the Curve of Efficiency for the common marine, unjacketed, single cylinder, condensing engine; C is the Curve of Efficiency for the same engine using superheated steam; D is that of a "compound" jacketed, condensing, marine engine; E applies almost exactly to both non-condensing engines and compound engines of the best classes, and the curve F is practically correct for the last named class of engines when the steam is kept thoroughly dry by effective superheating and reheating in a receiver.

Curve B is thus obtained:

Collating Isherwood's with other experiments made for the United States Navy Department, which are almost the only valuable experiments for our present purpose ever made on this class of engine as used on our river steamboats and in the Naval Service,* we find the following relative measures of steam consumption at various ratios of expansion, and of work done by it:

Cut-off $\frac{1}{r}$ (real),	·1	·3	·5	·7	·9	1·00
" $\frac{1}{r^1}$ (apparent),	·05	·25	·47	·68	·89	1·00
Relative weights of steam,	·16	·41	·60	·76	·92	1·00
" "total work" done,	·21	·56	·82	·97	1·00	1·00

* "Researches in Engineering," Vol. ii, Table, p. xxxiv.

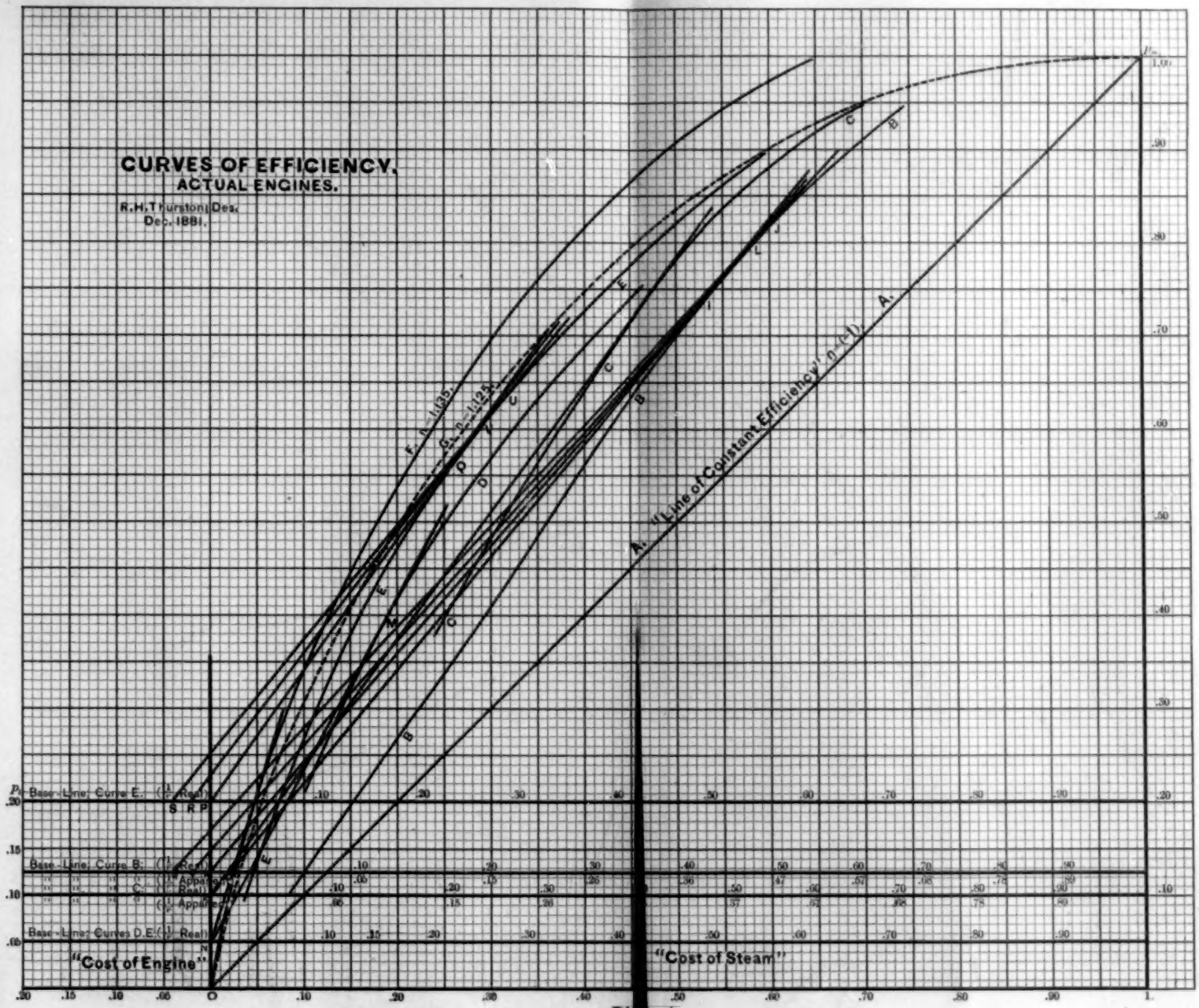

CURVES OF EFFICIENCY.
ACTUAL ENGINES.
R.H. Thurston, Des.
Dec. 1881.
"Cost of Engine"
"Cost of Steam"
A. "Line of Constant Efficiency" (1)
Base-Line, Curve E. (1) Real
Base-Line, Curve B. (1) Real
Base-Line, Curves D.E. (1) Real

Plate I.

The base line, B, for this case, in which $\frac{p_2}{p_1} = \frac{1}{8}$, is drawn on the plate, and on this line are a set of values of $\frac{1}{r}$ corresponding to the relative weights of steam as laid down on the bottom scale, ·10 above ·16, ·30 above ·41, etc., etc., and the ordinates erected at these points are made proportional to the total work done at those ratios of expansion, and, thus carefully laying down these points, the line $B_1 B$ is constructed as the Curve of Efficiency for the engine, of which those of the United States Steamers *Eutaw*, *Michigan*, and all "American River Steamboat Engines" are representatives.

In a similar manner, by collating the data obtained by the trial of the *Georgiana's* engine, using superheated steam, with the experiments of Hirn showing a reduction of exhaust waste by superheating, we obtain the Curve of Efficiency $C_1 C$ and the Base Scale accompanying it.

A set of experiments on the *Bache* gives the line $D_1 D$, and the curve $E_1 E$ is found, by trial, to meet cases of good work with non-condensing engines, unjacketed, but worked at high piston speed, and of some of the very best results obtained with compound engines of the most successful types.

Curve F seems to meet those cases in which superheating has been so efficient as nearly to prevent all condensation, and the line corresponds closely with the adiabatic for steam, dry initially, and only condensing so much as is due to the performance of work.

The location of these lines, as well as their form, is evidently variable with every change affecting efficiency.

The writer has been unable to find sufficiently complete series of experiments reported to construct these last curves as exactly and satisfactorily as the first, and has been compelled to work from scattered and comparatively incomplete data. The results, so far as comparable with practice, seem to indicate sufficient accuracy to have been obtained for such illustration as is here necessary; but extended experiments on the more modern engines—like those experiments for which we are indebted to Isherwood, on earlier forms—are much needed. Even curve B is not as far removed as it should be from the adiabatic curve since it is constructed on the assumption that re-evaporation could be neglected in the case studied, an inexact assumption, but one made necessary by the absence of data relating to

condensation at the point of cut-off.* The writer would be inclined to increase the proportion of loss taken from the record by at least an additional 10 per cent., making the total, probably, equal to

$$h_e = 0{\cdot}2\sqrt{r} \text{ nearly.}$$

To obtain an exact solution of these problems the quantity of steam present in the cylinder *at the point of cut-off* must be precisely measured and compared with the quantity sent to the engine from the boiler. This absolutely essential comparison has been very rarely made by engineers conducting trials of steam engines.

12. Method of Application of the Method and Use of the Diagram.

Comparing curves F and G, representing the case of steam expanding in a non-conducting cylinder, *i. e.*, adiabatically, with the other curves, obtained for expansion in real engines, it is seen, at a glance, that the more perfectly exhaust-waste by cylinder condensation is guarded against, the more closely does the actual engine approach to the perfect engine in its utilization of steam, and the less effective the provision against such loss the more widely does the Curve of Efficiency depart both in location and form from the ideal curve, finally approximating to the straight line of Constant Efficiency $A_1 A$. While the best engines approach comparatively near the curve of maximum possible efficiency, the great majority of condensing engines in use are of the class represented by that giving Curve B; which latter is, however, by no means a case of remarkably low efficiency. In many cases the curve will be found to fall within the line B.

Selecting one of these curves, as B, or C, we may solve either or all of the problems already defined by merely applying a straight-edge to the diagram. For B we have $p = 40$; $p_b = 5$; $\frac{p_b}{p_1} = \frac{1}{8} = 0{\cdot}125$. To determine the Ratio of Expansion at Maximum Efficiency, draw the base-line at the altitude 0·125 and from its junction with the ordi-

* In fact, the only nearly complete sets of essential data given on any engines are those published in reports of U. S. Naval Engineers. Investigators have not yet learned the importance of ascertaining, in every engine trial, the weight of water passing through the engine and of comparing it with the weight of steam present *at each point* of the stroke as measured by the indicator. Where experiments, otherwise valuable, have been made it has rarely occurred that any one set of conditions has been preserved constant, while observing other variables, so as to secure any useful data for investigations like the present. Professor Cotterill's treatment should be applied in every case to secure a full and satisfactorily valuable set of data.

nate at the zero point, draw the line *HI* tangent to the curve; it touches the curve at *I* and the corresponding ratio of expansion on the base line beneath is a trifle less than $\frac{1}{r} = 0{\cdot}4$; $r = 2{\cdot}5$ nearly—a result confirmed by reference to the original data.

Next ascertain the hourly or annual cost of supplying the engine with steam worked without expansion, including all items of expense variable with the quantity of steam used, and determine the *variable* part of all running expenses in the engine room, including interest, insurance, rent, cost of oil and so much of the wages of the attendants as is properly taken as variable with the size of engine. Suppose, as in a case taken by the writer, that the latter is found to be two per cent. of the former, $M = {\cdot}02$.

From the point *T*, at the ordinate ·02, on the left of the *H*, draw the tangent to the curve as *TL* on the curve *B;* its point of tangency identifies the best ratio of expansion for commercial efficiency.

Similarly compare the "cost of full steam" with the sum of all other running expenses chargeable to the plant; if the ratio is $N = {\cdot}04$, draw the tangent line *WL* from the ordinate ·04 and thus find that ratio of expansion which will give most work for the money expended on a plant already installed. The lines *PQ*, *RV* and *SU* thus determine these three ratios for the curve *F*, of a well-constructed non-condensing engine, using perfectly dry steam and with a ratio $\frac{p_0}{p_1} = 0{\cdot}20$. The line *NM* determines the ratio of expansion at maximum efficiency for the case *D*, a compound engine doing good work with $\frac{p_0}{p_1} = {\cdot}05$.

13. *Estimation of Expenses.*

The following example illustrates, in detail, the calculation of *M* and *N:*

Rated power of given engine and boiler,		500 HP
Working time, per annum,		3,000 hrs.
(*A.*) *Cost of engine* (*variable with size of engine*).		
Cost of engine,		$10,000
Annual interest at 6 per cent.,	$600 00	
" cost of repairs and depreciation, 4 per cent.,	400 00	
" " materials used,	50 00	
Total annual cost,	$1,050 00	

(*B.*) *Costs of boiler* (*variable with demanded boiler-power*).

Cost of boiler; actual, $12,000, for "full steam,"	$24,000
Interest on cost, using steam without expansion, at 6 per cent.,	1,440
Repairs and depreciation at 15 per cent.,	3,600
Minor expenses per annum,	200
Total annual maximum cost,	$5,240

(*C.*) *Fuel Account* (*variable with size of boiler*).

Coal, per year at the rated power,	2,000 T
" " " with no expansion,	4,000 T
Cost of fuel at "full steam," at $5 per T,	$20,000
" " transportation and storage at 50c.,	2,000
Total maximum per year,	$22,000 00

(*D.*) *Attendance* (*wholly or partly constant or variable*).

(*a*) "Engine-driver's" (engineer's) pay, per year,	$1,000 00
(*b*) "Firemen's" (stokers') pay, per year ("full steam"),	1,200 00
	$2,200 00

(*E.*) *Incidentals* (*constant as a rule*).

Rent, taxes, insurance, etc., per annum,	$1,000

Studying the statement of costs, the mechanical engineer decides in each case, and for each problem presented how the items should be grouped. For the case of a stationary steam engine such as is here presented, he would find:

$$M = \frac{(A)}{(B)+(C)} = 0{\cdot}035, \text{ nearly}$$

if the costs (D_a), (D_b) are not variable within the probable range of variation; or

$$M = \frac{(A)}{(B)+(C)+(D_b)} = 0{\cdot}03, \text{ nearly}$$

if the cost of fire room labor is variable with quantity of steam demanded. Then

$$N = \frac{(A)+(D)+(E)}{(B)+(C)} = 0.15 \text{ nearly}$$

for the first case, and

$$N = \frac{(A)+(D_a)+(E)}{(B)+(C)+(D_b)} = 0{\cdot}10, \text{ nearly}$$

for the second case. In marine steam engineering, storage becomes an important matter, in items (*A*) and (*D*); and (*B*) as well as very important in (*C*) and (*E*), since every cubic foot occupied by machinery, fuel or attendants displaces a cubic foot of paying loading. With very large powers, the items (*D*) both become to a certain extent variable, the one (D_a), with magnitude of the whole plant, the other (D_b) with quantity of fuel burned. Correctness in making up the bill of costs will be found to be absolutely essential.

14. Statement of Results.

Laying out these curves on a conveniently large scale and proceeding as just indicated, the writer obtained the results exhibited in Table I, here given. Cases I to VI, inclusive are obtained from Curve *E;* VII to XII from Curve *B;* XIII to XVIII from *E,* and XIX to XXIV from the best Curve of Efficiency, on the plate, Curve *F.*

The Ratio of Expansion at Maximum Efficiency of Fluid will be found in column r_e^{i}, that at Maximum Efficiency of Engine under r_e^{ii}, and the Best Ratio of Expansion for Commercial Efficiency, or for Maximum Efficiency of Capital is given under r_e^{iii}, *M, N,* are the ratios of cost. Comparing the first, and especially the second, set with the last, the enormous variation due to cylinder condensation is readily appreciated. Even the last case is far from the efficiency of the perfect engine.

The ratios of expansion for superheated steam in the unjacketed cylinder are obtainable from Curve *C.*

[P = Initial Pressures measured from perfect vacuum; P_3 = Back Pressure in cylinder; P_b = Same plus friction; M = Ratio of variable part of cost of engine to variable part of cost of steam, when $r = 1$.

$r_e^{i}, r_e^{ii}, r_e^{iii}$ = Ratios of Expansion of Maximum Efficiency of Fluid, of Engine and of Capital invested to obtain a Given Amount of Power with best engines of each class.]

The values here presented for these several cases are not to be taken by the engineer as exact for other examples. They are given as representative cases, and the engineer designing new engines should, whenever possible, construct his own diagram and make his own solution of the problem before him.

TABLE I.

Ratios of Expansion at Maximum Efficiency of Fluid, of Engine and of Capital.

SINGLE CYLINDERS.

Absolute Initial Pressures.			Case No.	Class I. Non-condensing, High Speed.							Case No.	Class II. Condensing, Moderate Speed.						
P	P_m	Atmospheres.		P_2	P_b	M	$\frac{p_1}{p_b}$	r_e^{I}	r_e^{II}	r_e^{III}		P_2	P_b	M	$\frac{p_1}{p_b}$	r_e^{I}	r_e^{II}	r_e^{III}
40	2·8	$2\frac{3}{4}$	I	18	20	·02	2	2	2	2	VII	3	5	·04	8	$2\frac{1}{2}$	$2\frac{1}{4}$	2
60	4·2	4	II	18	20	·02	3	3	3	$2\frac{3}{4}$	VIII	3	5	·04	12	$3\frac{1}{2}$	$3\frac{1}{4}$	3
80	5·6	$5\frac{1}{2}$	III	18	20	·02	4	4	$3\frac{3}{4}$	$3\frac{1}{4}$	IX	3	5	·04	16	$4\frac{1}{2}$	4	$3\frac{1}{2}$
100	7·0	$6\frac{3}{4}$	IV	18	20	·02	5	5	$4\frac{1}{2}$	$3\frac{1}{2}$	X	3	5	·04	20	$4\frac{3}{4}$	$4\frac{1}{2}$	4
120	8·4	8	V	18	20	·02	6	6	$5\frac{1}{2}$	4	XI	3	5	·04	24	$5\frac{1}{2}$	5	$4\frac{1}{2}$
150	10·5	10	VI	18	20	·02	$7\frac{1}{2}$	7	6	$4\frac{1}{2}$	XII	3	5	·04	30	6	$5\frac{1}{2}$	5

COMPOUND, CONDENSING, JACKETED.

Absolute Initial Pressures.			Case No.	Class III. Saturated Steam.							Case No.	Class IV. Superheated Steam.						
P	P_m	Atmospheres.		P_2	P_e	M	$\frac{p_1}{p_b}$	r_e^{I}	r_e^{II}	r_e^{III}		P_2	P_b	M	$\frac{p_1}{p_b}$	r_e^{I}	r_e^{II}	r_e^{III}
40	2·8	$2\frac{3}{4}$	XIII	3	$5\frac{1}{2}$	·04	7	6	5	3	XIX	$2\frac{1}{2}$	5	·05	8	8	6	5
60	4·2	4	XIV	3	$5\frac{1}{2}$	·04	11	8	7	$4\frac{1}{2}$	XX	$2\frac{1}{2}$	5	·05	12	11	8	6
80	5·6	$5\frac{1}{2}$	XV	3	$5\frac{1}{2}$	·04	14	9	8	6	XXI	3	$5\frac{1}{2}$	·05	13	14	10	7
100	7·0	$6\frac{3}{4}$	XVI	3	6	·04	17	10	9	7	XXII	3	$5\frac{1}{2}$	·05	18	16	12	8
120	8·4	8	XVII	3	6	·04	20	11	10	8	XXIII	3	$5\frac{1}{2}$	·05	22	20	15	9
150	10·5	10	XVIII	3	6	·04	25	13	10	9	XXIV	3	6	·05	27	25	17	10

Further investigation will, undoubtedly, sooner or later, establish the Curves of Efficiency for those classes of engine and for those special cases for which the engineer can to-day only obtain them approximately. Meantime, the plate exhibits a range of variation of curve which extends completely across the field of every-day practice, and an experienced engineer can readily trust his judgment in the interpolation of the curve of efficiency for any special case arising in his own practice. For example: Cases of best practice in which the engine is worked at higher speed, and with a warmer condenser, and having less friction, will give a curve for the class from which B was obtained, which will fall between B and C.

The values given of $\frac{p_1}{p_b}$ are interesting in comparison with the values of r_e, as exhibiting this enormous difference between the best ratio of expansion in actual work and the ratio giving maximum efficiency in the ideal case, and also as strikingly presenting to the mind how far we are still, in actual practice, from even an approximation to the ideal conditions exhibited in the perfect engine.

TABLE II.

Ratios of Expansion giving Maximum Work at Minimum Cost for a Given Plant of Known Proportions.

	Class I.						Class II.					
Cases	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
N	·04	·04	·04	·04	·04	·04	·10	·10	·10	·10	·10	·10
r_e^{iv}	$1\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$1\frac{3}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4

	Class III.						Class IV.					
Cases	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
N	·10	·10	·10	·10	·10	·10	·12	·12	·12	·12	·12	·12
r_e^{iv}	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	5	5	$5\frac{1}{4}$

Table II gives values, similarly obtained for the cases taken, of that ratio of expansion which gives a maximum quantity of work for a dollar with a fixed proportion of plant. These values are seen to be very much smaller than the ratios for maximum commercial efficiency, and, although they may give more work for a dollar than the

higher ratios just determined, they do not give maximum efficiency of capital. For:

Assume the engine working at this nearly adjusted ratio for the now given power, still more work will be given for the dollar if the value of r be increased by replacing the given engine by a larger one, in many cases, or in any case by speeding up the engine or otherwise doing the larger amount of work with the higher ratio of expansion. The writer has sometimes accomplished this latter result by both speeding up the engine and carrying higher steam,* with an automatic adjustment of expansion. The real limit to this increase of work done by the given engine is determined by quite other considerations than those above noted. It is determined by the money value of the power obtained, and this increase of power finds a limit, as has been seen, only when either the limit of safety in working engine or boiler is reached, or when the money made by the use of additional power is insufficient to pay a fair profit on the additional expense incurred, which latter limit may be obtained at a value of r^{iv} either equal to or less than r_v.

15. Relation of Costs and Profits.

Table III exhibits the effect of variation of actual value of the power in determining the maximum amount profitably obtainable from any engine.

For example: Suppose the cost of a horse-power to be, as is frequently the case, about equal to the cost of fuel (in the furnace) producing that power without expansion; then calling this value P_m and this cost P_c, the base line of the diagram will be extended until it measures $\left(\frac{P_m}{P_c} = 1 = N^1\right)$ twice the length of OX, and the angle made by the line from its extremity to A, Fig. 2, makes an angle $\theta = 45°$ with OX. On the large-scale drawing, set the triangle against the edge of the T-square, and adjust it to the line here given; find by shifting it along the blade that point on the selected curve of efficiency at which a parallel tangent can be drawn, and then the ratio of expansion, r^v, answering to this case, is found.

* A favorite occupation of the writer, when engaged in this branch of professional work, was that of designing new and larger steam cylinders for old engines, to meet this case.

If an engine, IV of Class I, is selected, it is found to be $r^v = 2\frac{1}{2}$; if No. VII of Class II, $r^v = 2$, etc., etc., as in Table III.

It is particularly interesting and instructive to observe how the importance of cylinder condensation, in its influence on the best ratio of expansion, diminishes with decreasing expansion, and that, finally, the most economical and the least efficient give nearly identical figures when the point of cut-off approaches half stroke.

TABLE III.

Effect of Variation of Ratio to Market Value to Cost of Power. Maximum Limiting Values of r^v.

		N^1	0·40	0·50	0·60	0·70	0·80	1·00
Class	No.	IV	.....	.....	.....	.....	3	$2\frac{1}{2}$
" II	"	VII	.....	.....	.....	.....	.....	2
" II	"	X	.....	.....	.....	.....	.....	2
" III	"	XV	.....	7	5	4	3	$2\frac{1}{2}$
" III	"	XVII	.....	7	5	4	3	$2\frac{1}{2}$
" IV	"	XXI	9	7	6	4	3	$2\frac{1}{2}$
" IV	"	XXIV	10	7	6	4	3	$2\frac{1}{2}$
θ			22°	27°	31°	35°	39°	45°

Taking the cost of fuel, *in the furnace*, for the engine working without expansion, at $50 per annum per horse-power, the above table gives the ratio of expansion below which a loss will accrue when the cash value of the horse-power is 20, 25, 30, 35, 40 and 50 dollars; at these ratios of expansion, all that is received for power above these sums is profit.

For other costs, the prices obtained must be correspondingly varied to secure a profit.

16. Profits at any Fixed Expansion.

Other problems, the converse of the last, may be solved by this construction: "What is the maximum price which can be paid for power without loss at any *given best ratio of expansion?*" "What profit is obtainable at lower costs?" "What total cost makes any given ratio the most economical ratio of expansion?"

To solve these problems, draw an ordinate to the line of mean pressures, or the curve of efficiency, at the assumed ratio of expan-

sion; the abscissa measures the cost in terms of full steam of the power measured by the ordinate, above which loss will accrue, when M = 0. The difference between the total cost and the price measures the profit obtainable if the power is sold at the higher of the two figures.

Table IV, exhibits the variation of the relative maximum allowable cost of power, with variation of the ratio of expansion, actual cost of expenses, variable with fuel without expansion, being taken as unity.

TABLE IV.

Maximum Limit of Relative Allowable Cost. Most Economical Ratio of Expansion assumed as r. Cost of Full Steam = Unity.

M or N = 0·1.

			r	1	2	3	4	5	6	8	10
Class	I	No.	IV	1·1	·80	·75	·75	·85	·85	.....	.....
"	II	"	VII	1·1	·80	·85	1.1	.....	.....	.....	.....
"	II	"	X	1·1	·75	·80	·95	.....	.....	.....	.....
"	III	"	XV	1·1	·75	·70	·70	·75	·80	·90	1·1
"	III	"	XVII	1·1	·75	·70	·70	·70	·70	·75	·90
"	IV	"	XXI	1·1	·75	·70	·90	·65	·70	·75	·90
"	IV	"	XXIV	1·1	·75	·70	·65	·65	·55	·55	·65

17. Cost of Engine as Affecting the Best Ratio of Expansion.

The effect of variation in cost of engine now becomes of interest, and indeed a matter of real importance to the designer. Studying cases arising in practice, he will probably find the value of *M* or *N* to fall between ·02 and ·15, as in those selected above, but it will probably rarely, if ever, exceed 0·20.

The curve being established correctly for any given engine, it becomes the easiest possible matter to determine the effect of variation of this ratio. Table IV gives such results as seem most instructive, from the cases here studied.

TABLE IV.

Effect of Variation of "Engine-cost Ratio." Best Values of r_e^{iii} *or* r_e^{iv}.

		M or *N*		·02	·04	·06	·08	·10	·15	·20
Class	I	Example	IV	3½	3¼	3	2⅞	2⅞	2½	2¼
"	II	"	VII	...	2	2	1⅞	1⅞	1⅝	1½
"	II	"	X	...	4	3¾	3½	3¼	2⅞	2½
"	III	"	XV	...	6	5	4¼	4	3½	3
"	III	"	XVII	...	8	6	4¾	4½	3¾	3¼
"	IV	"	XXI	...	6½	6	5½	4¾	3¾	3¼
"	IV	"	XXIV	...	9	7	6	5	4	3½

These differences in the value of the ratio of expansion at maximum commercial efficiency are least where the exhaust wastes are greatest, and as their absolute values become smaller. Cases IV, X, XVII and XXIV have the same initial steam pressure and are seen to approximate toward the same value of r_e as the value of M or N becomes greater, becoming, for the first two, and for the last two, nearly equal to the maximum value here taken.

It is obvious that the value r_e becomes a good gauge of the economical value of the engine, and that the greater these values and the nearer r_e^{ii}, r_e^{iii}, r_e^{iv} approach each other, in any given engine, the better the design.

It is now seen that we have here a method of determining the effect of variations of single variable quantites, while retaining all others constant—a method very greatly needed, but hitherto unknown.

The case just taken is an illustration of its application. The following is another instance of no less importance.

18. Back Pressure as Modifying Economy.

The Effect of Variation in Back Pressure may be studied, by means of this method of investigation, with the same facility.

Table V exhibits this effect for a wide range of cases.

Table V.

Effect of Variation of Initial Pressure and of Back Pressure.
Best Values of r_e^i.

		$\frac{p_b}{p_1}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{10}$	$\frac{1}{15}$	$\frac{1}{20}$
Class I	No. IV		$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{1}{2}$	...	...	...	...
" II	" VII		$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	...	...
" II	" X		...	...	...	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	3	4
" III	" XVI		...	...	...	$4\frac{1}{2}$	6	7	9	11
" IV	" XXII		...	...	...	6	6	8	12	15

These differences in value of r_e are obtained on the assumption that cylinder condensation and all other conditions remain unchanged while variation occurs in the back pressure. In all actual cases, the differences would be reduced by the fact that increased condenser-pressure and the reduction of chilling effect which comes with increase of back pressure so check exhaust waste that the ratio for maximum efficiency becomes somewhat increased and these differences of ratio

are thus lessened. The gain from this and other causes becomes sufficient at high pressures to justify the use of the simpler and less expensive non-condensing engine; it will be best appreciated after comparison of Class I with Class II.

19. Illustrations of the Value of Results.

In illustration of the use of this method and of the application of the results, we may observe as in Table I values of the ratio of expansion for maximum efficiency for any standard type of engine. Thus: Case III is that of an ordinary, standard, non-condensing, drop cut-off engine, steam 65 pounds ($5\frac{1}{3}$ atmospheres) by gauge, and the cut-off occurs, properly, at a little inside $\frac{1}{4}$ stroke; Case V is the same with steam at 105 by gauge (8 atmospheres) and its valve should close a little inside $\frac{1}{5}$ stroke.

For maximum *commercial* efficiency those engines should "cut off" at about $\frac{1}{3}$ and $\frac{1}{4}$ respectively.

In the second class, Case VII is that of the old naval or modern very low-pressure river-boat engine carrying 25 pounds of steam by gauge ($2\frac{2}{3}$ atmospheres). The valve should drop so as to completely shut off steam at about half stroke to give minimum expenditure for coal and a little later to give minimum cost on total account,* a result already reached by the builders of such engines.

Case VIII is that of some of our Hudson river steamboats (steam 45 by gauge) and these two ratios are found to be a little greater and a little less than 3.

The irregularity of wheel which a short cut-off produces, however, makes it inadvisable to expand as much as this, even.

Case IX is often seen in mill engines; its valve closes at $\frac{1}{4}$ and $\frac{1}{3}$ for the cases taken. Above this pressure, a comparison of Class I with Class II shows that in the cases taken the non-condensing engine is about as economical as the other—a conclusion justified by Isherwood's comparison of Corliss engines†—but comparing values of r_e^{iii} it is seen that the condenser may probably be exchanged for the heater with Classes III and IV only at some very high pressure not yet

* Engines of this class by good builders, having the "Stevens Valve-gear," close the valve at 6 feet on a 10 feet stroke, which, allowing for a little throttling, gives exactly this figure. Those fitted with the "Sickles Cut-off," drop the valve as near half-stroke as possible; they cannot "follow" further.

† Journal Franklin Institute, Sept., 1881.

attained with jacketed engines of good design, while the ten per cent. gain obtained at the boiler by the higher temperature of feed given by the heater of the non-condensing engine, together with the differences in size of cylinder, brings down the pressure at which total efficiency becomes a minimum to some lower figure which may be determined, by the method here given, for any given case.

Cases XV and XVI are commonly illustrated on transatlantic steamers and by the best compound pumping engines. The cut-off takes effect at $\frac{1}{8}$ or $\frac{1}{9}$ for maximum efficiency of engine and fuel, and at $\frac{1}{6}$ or $\frac{1}{7}$ for most economical expenditure of money,* figures already settled upon by the most successful builders.

Cases XII and XIII represent the most advanced practice in the use of high steam pressure, superheated steam and reheating at the intermediate receiver, as is done in the pumping engines of Cowper, Corliss and Leavitt. The best ratios of expansion are 12 and 15, if measured by duty attained and fuel saved, simply, and two-thirds those values give maximum efficiency of capital. Case XXIV represents most nearly the case of Corliss' best pumping engine, which lies between XXIII and XXIV, its best ratio of expansion lies between 9 and 10, if the Curve of Efficiency here taken for Class IV suits that case. If nine is the *real* ratio, the *apparent* cut-off will be nearly at one-tenth, while for maximum efficiency of engine and maximum "duty" the valve should drop at about one-sixteenth stroke.

It should be carefully kept in mind that the measure of cost, in all problems relating to expense, as here treated, is the total cost per annum, without expansion, of all items of Class 3, *i. e.*, variable with variation of steam supply.

The problem illustrated by the cases taken up in Table II would seem to be of rare occurrence. In fact, the writer has been able to imagine but two such cases:

(1). Where the proprietor of an engine can rent power from an engine already set up with boiler power sufficient to supply an ample amount of steam, he will obtain the best return from his invested capital by delivering so much power at remunerative prices as will give the values r_e^{IV}, found in Table II. Cases IV, V and VI are such as are most usual, the best point of cut-off averaging about $\frac{1}{3}$ stroke.

Had the power to be demanded been known, the proprietor would

* *Vide* "Clark's Manual for Mechanical Engineers," pp. 888, 890.

have done better to have put in a larger or a faster running engine with a higher ratio of expansion, and would usually find it economical to alter the engine here assumed to be used—in the manner already described—if possible, so as to deliver the maximum power, working at the shorter cut-off.

(2). The second is that of a naval engine intended to work with maximum efficiency at low power or long runs and only requiring high power for short periods of time. It has sometimes been customary to design such engines to work with high ratios of expansion while cruising, and to develop full power with less expansion when in action, supplying a fan blast for the latter occasion. For such cases the best ratio at low power would be r_e^{ii}, and it might be well to make the expansion variable through as wide a range as from r_e^{ii} to r_e^{iv}, taken with extreme values of M and N. As already stated, in all ordinary work, the Ratio of Expansion at Maximum Commercial Efficiency is the ratio of expansion to be adopted for any engine.

The values here given for M and N are based on cost of fuel taken at $5.00 per ton. The value of the ratios of expansion at maximum efficiency will be less at lower prices and greater at higher costs, the expenses of maintenance of plant being constant, since the values of Cost of Steam will be directly and of M inversely as the price of fuel. With coal at ten dollars per ton, M will be practically one-half the figures given above and the least ratio of expansion correspondingly increased as per table V.

Table III may be consulted by the owner of steam power for cases which, as is usual, fall within the given limits. For exceptional cases he, or his consulting engineer, can, when data are obtainable, always make his own curve of efficiency and obtain a practically exact solution of the case presented.

20. Variation of Cylinder Condensation with Expansion.

One other among the numerous problems capable of solution by this most prolific of methods promises, in the opinion of the writer, to prove, in the future, both interesting and important:

"*Given:* the method of variation of efficiency with varying ratios of expansion or proportions of steam used, to determine the method of cylinder condensation with varying values of $\frac{1}{r}$."

To solve this problem, construct the Curve of Efficiency, as A, D,

E, O, Fig. 2, and draw the curves of adiabatic mean pressures for various values of x, as in dotted lines in that figure.

The points of intersection of these curves with the curve of efficiency identify the ratios of expansion at which the total condensation amounts to the proportion due to the adiabatic line so cut.

In all problems of maxima or minima solved by the construction here given it will be observed that the item of quantity of expenditure made the independent variable is that dependent upon the quantity of steam or of fuel demanded by the engine.

21. Problems solved by the Inspection of the Diagrams.

An important class of problems of simple character may be solved with still greater ease and rapidity by the use of the Curve of Efficiency for the class of engine studied in any case, *e. g.*:

(1). To determine the gain or decrease of power obtainable by change of ratio of expansion or point of cut-off, measure the ordinates of the curve at the present and at the proposed ratio of expansion; their relative magnitude will be a measure of the relative power of the engine at the two points of cut-off if using the quantity of steam measured by the abscissas.

(2). To determine the quantity of fuel or of steam, per hour per horse-power, to be gained or lost by change of the ratio of expansion, compare the value of ratios of abscissa to ordinate at the existing and proposed points of cut-off; their relation will be that of cost of power in steam or in fuel.

(3). To determine the absolute amount of fuel or of steam per horse-power and per hour consumed, at any assumed rates of expansion, first calculate the consumption for the given engine as a thermodynamic problem simply, and multiply by the ratio, $\frac{y}{p_m}$, of the mean pressure in the perfect engine at the given expansion to that shown by the true Curve of Efficiency for the engine studied. Or, calculate the consumption for the engine working without expansion and without waste, and multiply by the ratio, $\frac{p_1}{p_m y}$, obtaining y and p_m from the diagram N, the given cut-off, and remembering that p_1 measures the mean pressure at full stroke of the given steam used *dry*.

It is evident that when costs of engine can be referred, as here taken, to the same unit of volume, the solution of the problem of

maximum commercial efficiency is independent of size of engine and of the absolute measure of power demanded and hence applies to all engines of the same pattern.

22. Conclusion.

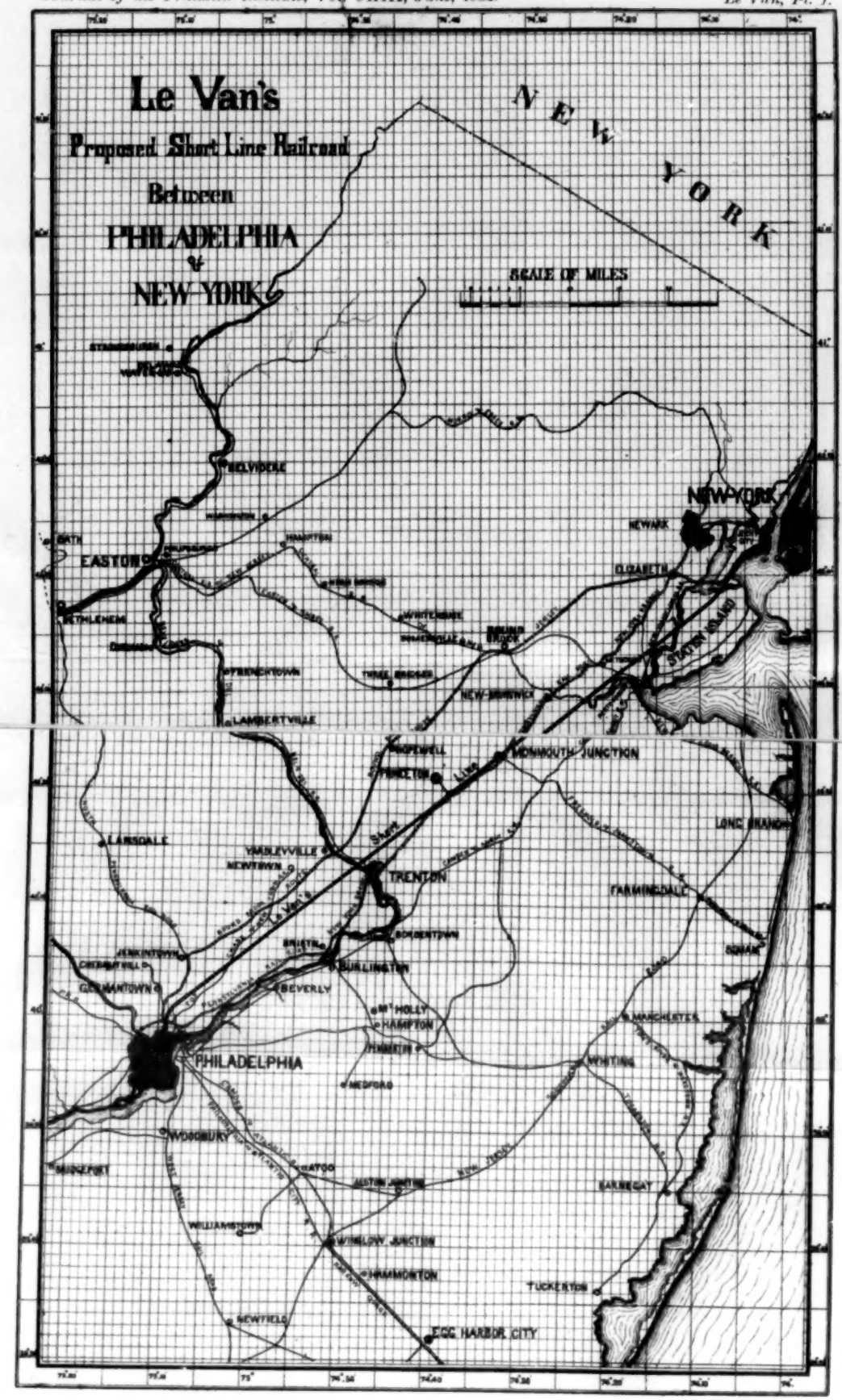
In view of what has preceded, it becomes obvious that the engineer purposing to write a specification for steam machinery on which bids are to be made with guaranty of performance should *first* determine the probable *Curve of Efficiency* for the Kind of Engine called for and solve the above problems relating to its economy. He should then prescribe the ratio of expansion at which maximum duty is to be obtained, as well as fix the duty expected in regular work, at which ratio the work done will be less than the regular working power of the machine. He must also indicate at what degree of expansion the engine will be required to do its ordinary work at maximum *commercial* efficiency, and should state what minimum commercial economy at that rate of work will be accepted. Finally, it should be prescribed that the engine should be capable, if its work should be increased, of attaining at least its maximum "efficiency of plant" with safety, and with a specified efficiency which should be reasonably high.

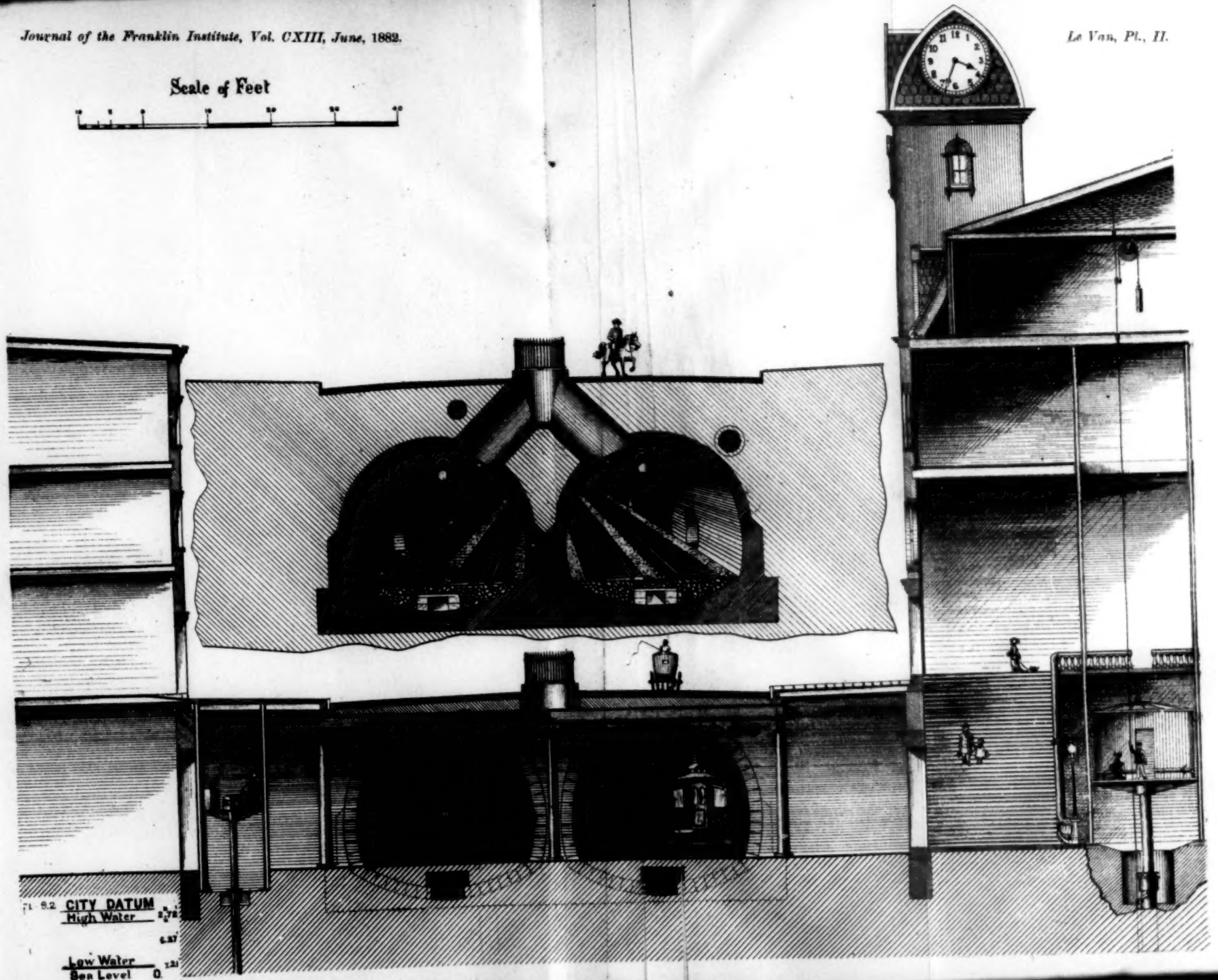
Thus fixing the ratio of expansion on the duty-trial, the builder is able to give an intelligently estimated guaranty of performance at highest efficiency; settling the ratio of expansion for maximum commercial efficiency in regular work fixes the proper size of engine, and the last specification secures ample strength of parts. Costs must be carefully estimated for the given locality. In what has preceded, the calculations have been based on cost of fuel estimated at $5.00 per ton, and labor at $2·00 to $3.00 per day, and interest at 6 per cent.

In laying out the curve of efficiency from experimental data it will be found necessary to be especially careful to establish the usually irregular scale of $\frac{1}{r^3}$, the points of cut-off, in their correct relation to the regular scale of steam expenditure and "cost of steam."

By the use of this, or some more exact method, the art of proportioning the steam engine can be elevated to the rank of a branch of the Science of Engineering, and that part of that science which has hitherto been in a most unsatisfactory, as viewed from the standpoint of the engineer engaged in its application, may be found to take a comparatively complete and useful form.

Journal of the Franklin Institute, Vol. CXIII, June, 1882. Le Van, Pl. I.


Le Van's
Proposed Short Line Railroad
Between
PHILADELPHIA
&
NEW-YORK
NEW YORK
SCALE OF MILES
NEW-YORK
NEWARK
ELIZABETH
STATEN ISLAND
EASTON
BETHLEHEM
BELVIDERE
LAMBERTVILLE
NEW-BRUNSWICK
MONMOUTH JUNCTION
PRINCETON
TRENTON
LONG BRANCH
FARMINGDALE
LANSDALE
YARDLEYVILLE
NEWTOWN
BRISTOL
BURLINGTON
BEVERLY
MT HOLLY
HAMPTON
MEDFORD
PHILADELPHIA
GERMANTOWN
WOODBURY
MANCHESTER
WHITING
BARNEGAT
WILLIAMSTOWN
WINSLOW JUNCTION
HAMMONTON
TUCKERTON
EGG HARBOR CITY
NEWFIELD


Scale of Feet
CITY DATUM
High Water
Low Water
Sea Level

Saltersville, thence along the east side of the Morris Canal to Fish Point, and ending at a point between Ellis' Island and the New Jersey Central Railroad Station in Jersey City, one mile distant from the Battery, New York City, a distance of about eighty miles. None of the crossings to be on grade, and but three curves, and these all of more than 10,000 feet radius.

Plate II shows a section of the proposed station and road-bed at Broad and Arch streets, Philadelphia. The upper section shows a section of the road-bed at Broad and York streets, the difference in height of the two road-beds being the difference in grade between the two points.

Owing to the nature of the country through which it will pass the road-bed can be made nearly perfect. Such road should be lighted by the electric light along its whole length, the telegraph poles which average thirty to the mile could be utilized for supporting the lamps, thereby relieving the locomotive of its headlight and avoiding the necessity of lighting up the cars.

By this route a business man would be able to make a trip either way in one hour, and would be enabled to transact business and return the same day, and have several hours in his own counting-house, an important advantage to a large portion of our business community. By this means a very great object will be gained, for although the trip can now be made in two hours either way, it would be of double or treble importance to enable any one to make the journey in one half the time.

Each city has certain advantages different from those of the other, and it would be to the mutual interest of both could they be brought closely in connection one to the other. It is well known that both cities are growing very rapidly. New York now numbers over one million inhabitants and Philadelphia nearly the same. With the great increase in numbers, and with the growing tastes of modern times for greater accommodation and luxury, as evidenced in the prevailing costly style of residences, hotels, etc., we may be sure that improved railroad facilities will be demanded, and it is quite time to consider, if, indeed, the question is not already under consideration, how these may be accomplished.

I believe that the present roads will be wanted exclusively for freight, and that we require a direct road between the two cities for the accommodation of passengers only.

In laying out an important work of this kind, it will naturally be expected the best railways in the world will be looked to, as furnishing most important experience, and some cue as a guide. I have examined carefully some of our best engineering works, and studied those abroad, and am satisfied from all my investigations that there is no difficulty in building a connecting link between the two cities that will make to its stockholders a handsome return of the money invested.

The best evidence that there is a demand for fast speed is the fact that scarcely a day passes over but that on the Pennsylvania Railroad its "flying trains" must be divided up into sections and run at intervals of twenty minutes to accommodate those who are anxious to be carried at *high speed.*

In this age of steam and the state of the art there is no excuse for the lack of enterprise which fails to supply rapid transportation of such good quality and at so cheap a rate as not only to command the monopoly of the traveling community, but also, if possible, to entirely exclude rival and competing lines; that is to say, it would pay to build and maintain a line so perfect as to render the construction of additional lines a hazardous speculation, and so much better in all its appointments and details than existing lines as to draw the trade from the different points common to all, and to have it so well managed by continually increasing its accommodations as to secure the traffic from the districts already covered by existing lines; and to insure safety, speed and low fares, especially the latter, is what is now wanted by the traveling and business community, and what will be to the interest of railroad stockholders.

It has been found that the most secure profits in any business are those derived from low prices and a large consumption. On this principle it is considered good economy to obtain control of a route that can be run safely, rapidly and cheaply, even at the expense, if necessary, of a considerable outlay in the first construction.

In building a railroad there is a peculiar feature in regard to its economical running, in which it differs from the economical working of an ordinary manufacturer or machinist. A railroad must be as nearly perfect as possible when it is first constructed, as improvements made afterwards cost double, as for instance, the straightening of the Pennsylvania Railroad between this city and Lancaster. A manufacturer of cotton or woolen goods, or a steam engine builder may at any time most convenient to himself add expensive and more economical

machinery or buildings, and thereby produce a better or a cheaper article; but in building a railroad this cannot be readily done. If the road bed is not originally well laid out and constructed, and capable of being run cheaply and safely it can only be reorganized at a cost equaling that of a new line. All advantages must be secured, and the outlay made in the first instance, if the stockholders are to receive any advantage from the money they have invested.

RINGING BELLS.

By JOHN W. NYSTROM.

(Continued from page 376.)

In connection with the article on "Intonation of Chime Bells," published in the May number of the JOURNAL, it is proposed to give the dimensions and weights of bells corresponding to each keynote in the eight octaves. For this purpose it is necessary to assume an average proportion of form, particularly that of the diameter at the bell-mouth to the thickness of the sound-bow, namely, $D:S = 1000:78$.

D = diameter of the bell in inches.

S = thickness of the sound-bow in inches.

n = double vibration per second, corresponding to the pitch of tone.

W = weight of the bell in pounds avoirdupois.

Diameter, $D = \frac{20592}{n}$. $\log.D = 4{\cdot}3136985 - \log.n.$

Weight, $W = \frac{204320000000}{n^3}$. $\log.W = 11{\cdot}3103144 - 3\log.n.$

The following tables of diameter and weight of bells are calculated from the above formulas, in which it is assumed that $S = 0{\cdot}078D$. For other proportions of S and D the diameter and weight of the bell will vary accordingly.

In old peals, all the bells are generally made of the same proportion, and even now some bellfounders hold to the old custom, probably for the reason that it is then easier to make the bell of correct pitch. When the proportion of S and D varies, as it should do for properly graduating the timbre in peals, it requires more knowledge of acoustics to make the bells right.

TABLE I.

Keynote, Diameter and Weight of Ringing Bells.

Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
2 C	156·	88,836	
B	165·27	105,645	Great Bell of Nishni-Nov-
A♯	175·11	125,635	[gorod.
A	185·52	149,405	
G♯	196·55	177,674	St. Ivan's Bell. Cast 1817.
G	208·24	211,291	
F♯	220·62	251,267	
F	233·74	298,813	
E	247·64	355,380	
D♯	262·36	422,573	
D	277·95	522,543	Great Bell of Moscow.
C♯	294·50	597,656	[Cast 1736.
1 C	312··	710,688	
B	330·56	845,285	Trombone Basso, lowest
A♯	350·21	1,005,100	[note.
A	371·04	1,195,240	
G♯	393·10	1,421,400	
G	416·47	1,690,300	
F♯	441·24	2,010,100	
F	467·48	2,390,600	
E	495·50	2,844,900	Contra Basso, lowest note.
D♯	524·72	3,380,600	
D	555·93	4,020,400	Contra Fagotto, lowest
C♯	589·00	4,781,500	[note.
0 C	624·	5,685,510	Bombardone, lowest note.

* St. Paul, London. Cast 1716.
† Lincoln, Eng., 1834.
‡ Bell of St. Peter's, Rome.
‖ Bell of Montreal. Cast 1847.

Table II.

Keynote, Diameter and Weight of Ringing Bells.

Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Bells and Musical Instruments.
C	39·	1,388	
B	41·32	1,650	
A♯	43·78	1,964	
A	46·38	2,334	Standard tuning fork, 440 vib.
G♯	49·14	2,776	
G	52·06	3,301	Highest note on Bombardone.
F♯	55·15	3,926	[Phila.
F	58·43	4,669	Tenor bell, St. Mark's Ch.,
E	61·91	5,552	Highest note on Contra Fag- [otto.
D♯	65·59	6,603	[Phila.
D	69·49	7,852	Tenor bell, St. Stephen's Ch.,
C♯	73·62	9,338	Old Lincoln. Cast 1610.
C	78·	11,104	
B	82·64	13,206	
A♯	87·55	15,705	
A	92·76	18,675	Bell of Brussels, Belgium.*
G♯	98·28	22,212	Oxford, Gr't Tom. C't 1680.†
G	104·12	26,412	Bell of Cologne. Cast 1447.
F♯	110·31	31,409	York, England. C't 1845.‡
F	116·87	37,350	Bell of Erfurt. Cast 1487.‖
E	123·82	44,422	Bell of Westminster, Eng.§
D♯	131·18	52,822	Bell of Olmutz, Bohemia.¶
D	138·98	62,816	Lowest note on Clarinetto, B fl.
C♯	147·25	74,707	Lowest note on Clarinetto, A.
C	156·	88,836	

* Lowest note on the Clarinetto C.
† Bell of Vienna, Austria.
‡ Lowest note on Guitar.
¶ Bell of City Hall, New York.
¶ New bell of St. Paul's, London, 1881.

Table III.

Keynote, Diameter and Weight of Ringing Bells.

Keynote.	Diameter, Inches	Weight, Pounds.	Remarks on Musical Instruments.
C	9·750	21·69	Highest note on C Flute.
B	10 33	25·79	Highest note on C Clarinetto.
A♯	10·94	30·67	
A	11·60	36·48	
G♯	12·28	43·38	Highest note on Clarinetto A.
G	13·02	51·59	
F♯	13·79	61·34	
F	14·61	72·95	
E	15·48	86·76	
D♯	16·40	103·2	
D	17·37	122·7	
C♯	18·41	145·9	
C	19·5	173·5	
B	20·66	206·3	
A♯	21·89	245·4	
A	23·19	291·8	
G♯	24·57	347·0	
G	26·03	412·7	
F♯	27·58	490·8	
F	29·22	583·6	Lowest note on Piccolo E flat [Flute.
E	30·96	694·1	
D♯	32·80	825·3	
D	34·75	981·5	Lowest note on Piccolo C, [Flute.
C♯	36·81	1167·	
C	39·00	1388·	

Table IV.

Keynote, Diameter and Weight of Ringing Bells.

Keynote.	Diameter, Inches.	Weight, Pounds.	Remarks on Musical Instruments.
8 C	2·437	0·339	Produced by the wings of a gnat.
B	2·582	0·403	
A♯	2·736	0·479	
A	2·899	0·570	
G♯	3·071	0·678	
G	3·254	0·806	
F♯	3·447	0·958	
F	3·652	1·140	
E	3·869	1·356	
D♯	4·200	1·612	Highest note of Piccolo E flat [Flute.
D	4·323	1·917	
C♯	4·601	2·280	
7 C	4·875	2·71	Highest note of Piccolo C Flute.
B	5·165	3·224	
A♯	5·472	3·834	
A	5·797	4·560	
G♯	6·142	5·422	
G	6·507	6·448	
F♯	6·894	7·668	
F	7·304	9·199	
E	7·739	10·84	
D♯	8·200	12·90	
D	8·686	15·34	
C♯	9·203	18·24	
6 C	9·750	21·69	

The Moscow great bell is the largest ever cast, being 272 inches in diameter and answers to the keynote D in the second octave, and weighs 432,200 pounds. It does not correspond exactly with the accompanying tables, for the reason that the sound-bow is $S = 0{\cdot}084D$.

The lowest note C, in the table, making $n = 33$ double vibrations per second, requires a bell of 52 feet in diameter, weighing 2550 tons, but by making the sound-bow $S = 0{\cdot}05D$, the same note would require a bell of only 400 inches, 33·3 feet, in diameter, weighing 430 tons. If the question was only to make a bell that would produce the lowest note C, making $n = 33$ double vibrations, without any other condition, the sound-bow may be taken $S = 0{\cdot}01D$, which would make the diameter only 80 inches, or 6 feet 8 inches, and the bell would weigh 1536 pounds. On the other hand, if the sound-bow is taken $S = 0{\cdot}1D$, which is sometimes done in bells, then the diameter for the same note would be 800 inches, or 66 feet 8 inches, and the weight of that bell would be 15,360,000 pounds or 6857 tons.

The above examples are only to show how the dimensions and weight of a bell can vary for the same keynote.

The preceding tables give the diameter and weight of bells of the most ordinary proportions.

[The discussion of this subject may be continued in a future number of the JOURNAL.]

Distribution of Energy in the Normal Solar Spectrum.—In the experiments which led Langley to the conclusion that the rays of light and heat coincide in intensity he found that the actual amount of energy which is required in a ray in order to make its presence evident through photography is less than $\frac{1}{10000000}$ of the energy which would be required, under the most favorable conditions, to produce a perceptible change in the most delicate galvanometer, by means of the most delicate battery. Langley's first paper presented the result of more than 15,000 galvanometer observations during a single year. In view of the rapid and extreme changes of atmospheric transparency many successive years would doubtless be required to secure the greatest possible exactness. He expects, by means of his observations, to arrive at a satisfactory determination of the actual amount of heat which the earth receives from the sun.—*Ann. de Chim. et de Phys.* C.

RADIO-DYNAMICS: UNIVERSAL PHYLLOTAXY.

By Pliny Earle Chase, LL.D.

Bonnet's discovery of the tendency in plant-growth to arrangement in cyclical spirals, seems to have been wholly empirical. The law of formation is simple, each of the phyllotactic numbers, after 1 and 2, being obtained by adding the two preceding terms of the series. Such simplicity might have suggested an early extension of the law into other fields of science, if it had been subjected to an earlier mathematical investigation, but for fifty years it was regarded as marking a curious, though inexplicable and perhaps accidental harmony.

In 1849, some of the professors and students of Harvard University became convinced that a law, which is so widely prevalent, must have some reason for its being. Chauncey Wright, in the *Mathematical Monthly*, showed that it represented a tendency to division in extreme and mean ratio, a tendency which distributes leaves and branches in the way that is most favorable for nourishment and growth. Peirce and Hill (*ante*, p. 141) extended the law to the planetary system. The orbital period of Uranus is very nearly $\frac{1}{2}$ of that of Neptune; Saturn, $\frac{1}{3}$ of Uranus; Jupiter, $\frac{2}{5}$ of Saturn; Asteroid 139, $\frac{2}{5}$ of Jupiter; Mars, $\frac{2}{5}$ of Asteroid 139; Earth, $\frac{1}{2}$ of Mars; Venus, $\frac{8}{13}$ of Earth; Mercury, $\frac{2}{5}$ of Venus.

Laplace's discussion of the curious relations among the satellites of Jupiter furnished a satisfactory explanation of an exact commensurability which is uncommon in natural phenomena. His explanation was grounded upon elementary laws of oscillation, which should be operative in molecular, as well as in cosmical movements. We may, therefore, be justified in looking for indications, in chemical atoms, of tendencies which are variously developed in the realms of time and space.

It is easy to detect exact harmonies of sound when there are only a few thousand consonances in a second, but in luminous or other æthereal vibrations the case is different. I have shown (Note 149, *Proc. Amer. Phil. Soc.*, xix, 600) that if there are two harmonic light waves, the slower oscillating 1670 times, while the swifter oscillates 1843 times, there may be more than 300,000,000,000 coincidences of phase per second, and yet mathematical tests, which are commonly

satisfactory, may indicate a possibility that the harmony is merely accidental. For this reason it is always desirable, when practicable, to study harmonic groups rather than isolated harmonies.

In the discussions of Prout's hypothesis I do not find that any one has tried to test its general probability by mathematical methods. Whatever doubts may be felt as to the value of any given test, in a solitary instance, may be removed when it is taken only as a means of estimating comparative probabilities. In making my comparisons I have sought to neutralize the effects of personal equation or bias, as well as of accidental or empirical coincidence, by adopting Gerber's method of grouping and Clarke's recalculation of atomic weights. In view of the *á priori* probability of tendencies to division in extreme and mean ratio, I assume that the ratio of probability to improbability, in each instance, is at least $\frac{1}{4}$ D : (T — O); D being the tested divisor, T the theoretical atomic weight or nearest exact multiple of D, and O the observed atomic weight, according to Clarke's table. I have added Rb and Tl to Gerber's list of monatomic elements, and Bo, Ta and V to his tri- and pentavalent-list.

If we designate the several probabilities by $p_1, p_2, \ldots p_{64}$, that of Li being p_1, and that of Yb, p_{64}, the formula for aggregate probability, $P_a = p_a\, p_b \ldots p_n$, when applied to the several groups and to all the elements, gives the following results:

RELATIVE PROBABILITY.

Groups.	Hydrogen.	Gerber.	Phyllotactic.
Monatomic,	32·083	1·	1·232
Tri- and Pentavalent,	1·	24·916	24·916
Di- and Tetratomic,	1·	5375080·	7780740·
Metallic,	89507·6	1·	67·267
Aggregate,	1·	46·637	5592·649
Mean,	1·	1·062	1·144

My surprise at finding that the aggregate evidence of harmonic influence is so much greater in favor, both of Gerber's divisors and of my own, than in favor of the hypotheses of Dalton and Prout, will, doubtless, be shared by many. The uniformity of the evidence, in the separate groups as well as in the aggregate, that the phyllotactic divisors are more significant than those which are only approximately phyllotactic, will awaken no surprise in the minds of those who have learned that cyclical undulations in elastic media must be harmonic.

After I had found the above relations, Dr. Thomas Hill suggested the application of similar tests to the surd divisors, $\frac{1}{2}(3-\sqrt{5})$ and $\frac{1}{2}(\sqrt{5}-1)$. These surds represent the division in extreme and mean ratio, towards which the phyllotactic ratios continually tend. Dr. Hill's participation in Peirce's investigations gave him an interest in other researches of a like kind. As he was inclined to look upon perfect commensurability, such as Laplace found in the Jovian system, as exceptional, he thought that the fundamental ratios, $S_1 = \cdot 381966$ and $S_2 = \cdot 618034$, might be more exactly represented in atomicity than any of their approximations. The thought had so much likelihood that I gladly undertook the needful calculations, getting the results which are given in the following table.

RELATIVE PROBABILITY.

Groups	S_2	S_1	H.	Gerber.	Phyllotactic.
Monatomic,	2·085	1·00	30402·95	947·66	1167·08
3 and 5,	1·000	2·12	516·46	12867·90	12867·90
2 and 4,	1·000	2102·03	103214·80	$5548(10)^5$	$8031(10)^5$
Metallic,	1·840	3·28	89507·60	1·00	67·27
Aggregate,	1·000	3816·79	$378(10)^{14}$	$17633(10)^{14}$	$21145(10)^{16}$
Mean,	1.000	1·14	1·82	1·93	2·08

There is evidence, therefore, in each of the groups as well as in the aggregate, of a tendency to division in extreme and mean ratio at the very beginnings of chemical activity. In the di- and tetratomic group the probable influence of S_2 is to the probability of accidental or unknown influence only as 1·446 : 1, or very nearly as 13 : 9. Even this ratio, however, is satisfactory as an indication of incipient action, and suggests the belief that in the "nascent state," in the "fourth state of matter," or in some other approximation to the æthereal condition, S_1 and S_2 may be found to have as great a degree of relative importance as belongs to the phyllotactic divisors in the above comparisons. Dextro- and lævo-gyration, in plant-growth, in cometary and satellite revolution, and in optical chemistry, may, perhaps, represent the opposite tendencies of the two surd divisors.

The aggregate probability of hydrogen influence upon atomicity is more than 9,900,000,000,000 times as great as the aggregate probability of the influence of S_1. The corresponding phyllotactic probability is more than 5592 times that of hydrogen, or more than 55,400,-

000,000,000,000 times that of S_1, the latter being more than 3816 times that of S_2. Some helpful hints may, perhaps, be drawn from the fact that the greatest superiority of S_1 and S_2, as well as of the phyllotactic and approximately phyllotactic division over the hydrogen division, is found in the artiad group.

Thus, in every direction, multiply the evidences of the importance in all physical researches, of paying heed to the blended sway of inertia and elasticity. The principles which I applied successfully, in 1863, to barometric estimates of the sun's mass and distance (*Proc. Amer. Philos. Soc.*, ix. 287, 288; x. 375, 376, foot note) have been abundantly exemplified in every field in which I have sought for their application, and now I find them at the threshold of material structure, where cohesive and chemical attractions first show themselves. I do not wonder, then, when I find that the virtual areas of synchronous planetary reaction, or the mean instantaneous areas which a particle at sun's surface *tends* to describe about any given planet, are approximately phyllotactic. They evidently vary as $\sqrt{mr}$, and the closeness of the phyllotactic approximations is shown in the following table. The common ratio, $\frac{3}{4}$, is twice the phyllotactic ratio $\frac{3}{8}$. The factor 2 is also phyllotactic, indicating, perhaps, the reciprocal influences of equal action and reaction upon which each of the harmonies is grounded.

	Harmonic areas.	Mean virtual areas		Difference.
α	40·256	Jupiter,	40·587	—·331
$\beta = \frac{3}{4}\,\alpha$	30·192	Saturn,	30·063	+·129
$\gamma = \frac{3}{4}\,\beta$	22·644	Neptune,	22·675	—·031
$\delta = \frac{3}{4}\,\gamma$	16·983	Uranus,	16·782	+·201
ε	1·000	Earth,	1·000	·000
$\zeta = \frac{3}{4}\,\varepsilon$	·750	Venus,	·749	+·001
$\eta = \frac{3}{4}\,\zeta$	·562	.....	.....	.....
$\theta = \frac{3}{4}\,\eta$	·422	Mars,	·404	+·018
$\iota = \frac{3}{4}\,\theta$	·316	.....	.....	.....
$\varkappa = \frac{3}{4}\,\iota$	·237	.....	.....	.....
$\lambda = \frac{3}{4}\,\varkappa$	·178	Mercury,	·162	+·016

If earth were rotating with the speed which a coincidence of Laplace's limit, with the equatorial surface would give it, the time of rotation would be $2\pi\sqrt{r \div g} = 5073{\cdot}8$ seconds. Its coefficient of orbital rotation, therefore, is $86164{\cdot}1 \div 5073{\cdot}8 = 16{\cdot}982$, which is

equivalent to $\vartheta \div \varepsilon$. It is also nearly* equivalent to $a^{\frac{1}{4}}$, the nucleal radius in an expanding or condensing nebula varying as the $\frac{3}{4}$ power of Laplace's limiting radius. The locus of secular perihelion, or incipient rupture, for Uranus, is nucleally central between the mean loci of Jupiter and Neptune. I have often invited attention to the harmonic importance of the preponderating mass of Jupiter and the central position of Earth in the belt of greatest condensation. These renewed evidences of that importance lead me, through the doctrine of conservation of energy, to supplement Laplace's two laws of constancy by a third, viz.: *The sum of all the instantaneous virtual areas in a system will always remain invariable.*

The universality of photo-dynamic or radio-dynamic relations may be further illustrated by a new deduction of the identity of luminous and elementary gravitating velocity, which I first published in 1869 (*Proc. Am. Phil. Soc.*, xi. 103–107), but of which I gave foreshadowings nearly six years before. (*Ib.*, ix, 285, 357, 408; x, 269, *et al.*)

Coulomb's torsional formula may be applied to Sun's rotation, or circular oscillation, by taking Sun's equatorial semi-diameter, $r_\circ$, as the radial unit:

$$\int = \frac{m}{2} = \frac{W}{2} \cdot \frac{\pi^2 a^2 r_\circ}{gt^2} \; ;$$

$$\pi^2 a^2 r_\circ = \pi^2 l = gt^2 \; ; \; gt = v\lambda = \textit{velocity of light}. \qquad (1)$$

If Sun's apparent semi-diameter is 961″·1183, Earth's semi-axis major $(\rho_3) = 214{\cdot}45\ r_\circ$; g at Sun's equatorial surface $= {\cdot}0000003909446\ r_\circ$; $v\lambda = \rho_3 \div 497{\cdot}827 = {\cdot}4307721\ r_\circ$. Therefore, by substituting in (1), $t = 1101875$ sec.; solar rotation $= 2t = 2\ 5{\cdot}506$ days.

Haverford College, March 6, 1882.

Equi-potential Curves.—M. Guébhard has studied the colored rings, which are produced in a mixture of acetates of copper and lead under a thin leaf metal, placed at an equal distance from vertical needles, which are attached to the poles of a battery of high tension. The curves appear to coincide with the equi-potential systems, which the formula of Kirchhoff gives for a similar distribution of electric poles on an indefinite plane.—*Chron. Industr.* C.

* The difference is 6¼ per cent. which corresponds very closely with the secular eccentricity of Jupiter.

A THERMOGRAPH:

A New Apparatus for Making a Continuous Graphical Record of the Variations of Temperature.

By G. Morgan Eldridge.

[A Paper read at the Stated Meeting of the Franklin Institute, April 26, 1882.]

The instrument under consideration is a thermograph for recording the atmospheric temperature, the fluctuations of which are much less regular and more frequent than one who has not made a study of it would suppose. It records the temperature directly from the column of mercury in the tube of a thermometer by dots or perforations upon a sheet of paper previously ruled with degrees and hours.

Its principal parts are, as shown in Fig. 1 of Plate;

1st. A thermometer in the form of an ordinary mercury thermometer, but open at the top of the tube and having a wire entering the bulb and connected to one pole of a battery, the other pole of which is connected to the mechanism of the instrument.

2d. An upright cylinder revolving by clockwork, covered with a paper which is divided vertically into 24 parts by lines representing the hours, and horizontally by lines representing the degrees.

3d. A bar raised and lowered by mechanism driven by clockwork, furnished below with a needle entering the tube of the thermometer, and carrying a pencil—or preferably a point—driven forward by a small electro-magnet when the circuit is closed by the needle entering the mercury, and then making a mark at the proper place upon the paper and indicating the temperature.

The bar carrying the needle rises about half an inch from the point at which the needle leaves the mercury and then descends until the needle again touches the mercury, whether that in the meantime shall have risen or fallen, when the point makes its mark upon the paper and the bar again commences to rise.

This movement is accomplished by the mechanism shown in the drawing, of which only the wheel *E*, gearing into the rack upon the needle-bar, is shown in Fig. 1, but which is shown in full and upon an enlarged scale in Fig. 2, which is a top view. The two wheels *A* and *B* are moved by clockwork (not shown) and are constantly revolving

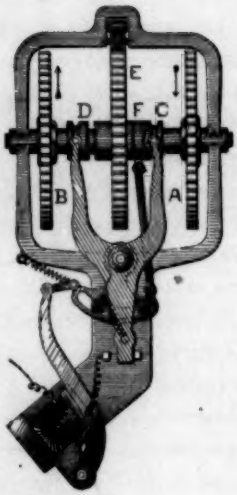


Fig. 2.

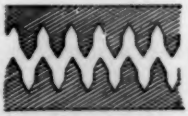


Fig. 3.

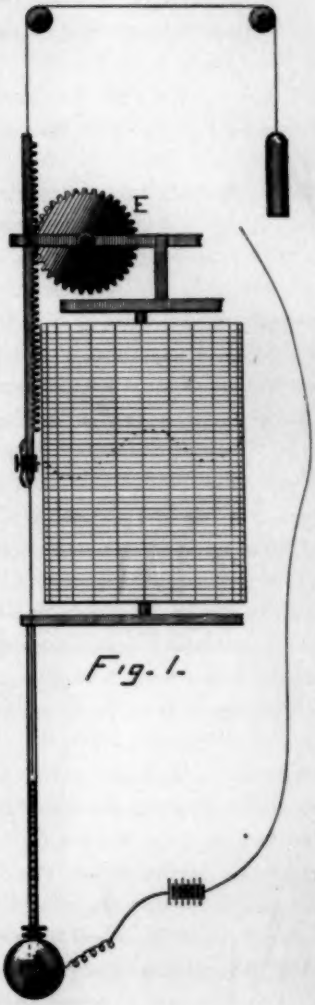


Fig. 1.

A NEW THERMOGRAPH.

in opposite directions, as indicated by the arrows. These wheels are not attached to the shaft upon which the wheel *E* is fixed, but are attached to sleeves which move without affecting that wheel except when they are joined to it by the clutches *C* or *D*. They are so geared that when the wheel *E* is joined to them its rim moves at the rate of half an inch per minute. Upon the shaft with the wheel *E* is also a loose sleeve *F*, which is free when the clutch *C* is not in action, but which moves with that wheel when that clutch is on.

The levers actuating the two clutches unite and move upon a common pivot, from which point they extend as an arm, which is capable of a lateral movement between two stops, bringing one or the other of the clutches into action.

Opposite to the wheel *E* the needle-bar passes through a guide which is furnished on the back with a small wheel taking the thrust of the gear and reducing friction. For a lower guide the needle-bar is furnished on each side with a rod parallel to the needle, and of nearly the same length. These rods are at such distance apart that they pass clear of the thermometer tube. They are not shown in the drawing, as they would lie directly in front of and behind the needle and tube.

The teeth of the clutches are partly V-shaped and partly square, or nearly so, as shown in Fig. 3; that is, they have slightly tapered sides but V-shaped points and bases, so that they enter freely, as entirely V-shaped teeth would do, and when in action they have no outward thrust. The V-shaped base strengthens the tooth and admits the point of the opposite tooth.

A very small spring on each side of the sleeve *F* holds it out of gear while the clutch *C* is off.

Beneath the clutch arm is a pressure spring, one end of which presses against the end of the arm and the other against a plate moving upon the same pivot with the arm, which plate also is capable of a lateral movement between its stops.

If this spring-plate is moved in either direction to its stop, carrying with it the base of the spring, the clutch-arm will be moved in the other direction and the clutch on that side will be brought into action; and if the position of the spring-plate with the base of the spring be reversed, the position of the clutch-arm will be reversed—that clutch will be disengaged and the other one will be engaged—the wheel *E* being moved and the needle-bar raised or lowered accordingly.

To the sleeve *F* is attached an arm which is connected by a draft rod to the spring-plate.

When the clutch *C* is in action—as shown in the drawing—connecting the wheel *A* with the wheel *E* and the sleeve *F*, raising the needle-bar, the arm of the sleeve *F* draws upon the spring-plate—moving to that side the base of the reversing-spring, which, when its base has passed the line between the pivot and the end of the clutch-arm, presses that arm to the other side, disengaging that clutch, loosing the sleeve *F*, engaging the other clutch, and reversing the motion of the needle-bar, which now descends.

The length of the arm on the sleeve *F* is such that when the needle-bar has risen half an inch the spring-plate is moved over, and the clutch-action is reversed.

When, by descending, the needle is brought in contact with the mercury and a circuit is made, the large electro-magnet, thus vitalized, attracts its armature, which is attached to a lever connected with and drawing upon the spring-plate, and moves the base of the reversing spring to that side, changing the position of the clutch-arm and reversing the action of the clutches and the movement of the needle-bar, while at the same time the recording point upon the needle-bar is, by its electro-magnet, driven into the paper and the temperature is recorded upon the scale.

The sleeve *F*, being loose, yields to the movement of the spring-plate, and is afterwards held by its clutch, and acts as before.

The action of the large electro-magnet is supplemented by that of a spring drawing upon the same side of the spring-plate, whose strength is such that it is not quite sufficient of itself to overcome the thrust of the reversing spring, but whose force is greatest when that of the electro-magnet, by reason of its distance from its armature, is least, the greatest possible portion of the work being thus put upon the clock-work and the least upon the battery.

This spring aids the electro-magnet, but does not in anywise reduce the effect of the reversing spring in holding the clutch to its work; so long as the base of that spring is unmoved its action is unimpaired. The resistance of these springs occurs only during the ascent of the needle-bar, which is, therefore, counterpoised to excess, and the resistance and the motion are thus rendered uniform. By reason of the form of the clutch-teeth before described there is no outward thrust upon the clutches while in action, and hence the reversing spring

requires only to be strong enough to throw the arm over and to shift the clutches. The stop of the clutch-arm next the electro-magnet is an insulated plate to which the battery-wire leading from the magnet is connected, so that as soon as the arm has left the stop the circuit is again broken, although the needle may for a short time remain in contact with the mercury; the recording point is at once withrawn, and thus makes upon the paper a single perforation which must be a true record of the position of the mercury in the tube, unaffected by friction or other disturbing cause, since this action must always take place at the moment of contact of the needle with the mercury, and these dots or perforations are repeated at the end of each interval of time required for the needle-bar to ascend and descend the required distance, which will be about two minutes with the wheel-motion designated.

The graduation of the scale upon the paper must correspond with the movement of the mercury in the tube of the thermometer as accurately as the graduation of the scale of an ordinary thermometer corresponds with the movement of the mercury in its tube.

If but one instrument of this sort is to be made this is very easy, the rate of motion is ascertained, a scale is made to fit it, and the paper is ruled to that scale.

In all thermometers heretofore made the scale has been made to fit the tube, but if more than one of these instruments is to be made it becomes necessary, or at least very convenient, to have one set of ruled papers that will fit all the instruments, and it then becomes necessary to reverse the practice and to make the tubes to fit the scale.

The rise and fall of mercury in a thermometer depends upon the proportion between the diameter of the tube and the volume of mercury in the tube and bulb, and while it is possible to construct these parts in such proportion as to obtain proximately a given motion, it is not possible thus to obtain it exactly.

The tube and bulb are made in separate parts, as shown in Fig. 1, of such size that when the tube is thrust half way into the bulb the volume of mercury filling the tube half way at 32° Fahrenheit is as nearly as may be properly proportioned to the diameter of the tube. If now there be found too much motion the capacity of the bulb is diminished by thrusting the tube further in, and *vice versa*, and the proper height of mercury at 32° for that purpose is marked upon the tube.

Mercury exposed to the air will slowly form a coating of oxide upon

its surface. To prevent this a small quantity of glycerin or of oil free from oxygen is placed in the thermometer tube above the mercury. If, notwithstanding, the oxide shall accumulate to an inconvenient extent the observer in charge of the instrument will remove the thermometer from its place, and will put the bulb in warm water until the oxide is floated off. He will then supply the loss with pure mercury, determining the proper quantity by immersing the bulb in broken ice, when the mercury column should stand at the mark for 32°.

The whole apparatus, except the thermometer itself, can be enclosed and so protected from the weather and dust, while the thermometer is exposed to the air below.

The system is equally applicable to a barometric record, in which case, on account of the small range of motion, the needle-bar is connected to a lever, thus increasing the range of the record.

ELECTRICITY.

By A. E. Outerbridge, Jr.

[Abstract of a Lecture delivered at the Franklin Institute, March 10, 1882.]

The subject of our lecture is one which offers unusual attractions at the present time, not only to the close student of science, but also to men of every profession or trade. The rapidity with which new discoveries in electrical science have followed each other of late years, together with the numerous practical and economical applications of the force to all sorts of industrial pursuits, and the prescience of still greater advances to come in the near future, has sufficed to render the subject an exceedingly popular one, and to lead many people to believe, whether truly or not, that electricity is the "coming force," which is to prove man's most useful servant, and is even destined, perhaps, to supplant steam power for many mechanical purposes, just as steam superseded human and brute force.

There is, I think, another explanation for the fascination attending, and the popular interest shown in, the study of electricity, which has little to do with its practical phase. I refer to the element of apparent mystery attaching to many of its phenomena.

There would seem to be a natural bias in many minds towards the mysterious, which not infrequently exhibits itself in an extraordinary

development of credulity, giving credence to the puerile teachings of self-elected professors of so-called supernatural agencies, known by various cabalistic names, such as "Psychic Force," "Odic Force," "Animal Magnetism," "Mesmerism," "Spiritualism," etc., but these various "isms," unlike the agency or force which will engage our earnest attention, have not been able to bear the light of careful searching investigation, nor have they been productive of any practical or useful advantage to man. Rather have they tended to befog the weak intellect and to create a doubt in the ill-balanced mind of the stability of nature's laws and the unity of her beneficent purposes, which all true scientific research tends so clearly to reveal.

Electricity as *an entity* was one of the earliest known of nature's agencies, having received its baptismal name more than two thousand years ago, and its sponsor was no less a person than one of the seven wise men of Greece. As *a science* it is the youngest of all her children, and is not yet out of its long clothes, although it is an amazingly precocious infant, having recently learned to talk, and we are astonished to find not only that its voice is strong and lusty, but also that its adaptability for all languages is without limit, reproducing the soft mellifluous tones of the Italian or Spaniard with the same ease that it does the harsher gutturals of the Teuton, the extraordinary syllabic enigmas of the Russian, or the peculiar labials of the "heathen Chinee." So admirable, indeed, are its linguistic accomplishments that it echoes the multitudinous tongues of men with the perfection of one "to the manor born," thus claiming recognition as an infant prodigy without an equal. It is difficult to realize that this youngest electrical child, which we call the "Telephone," is scarcely six years old; for its voice is now heard in all enlightened lands, and it has even become a very necessity of our modern civilization.

Although Thales made his famous experiment with amber more than five hundred years before the Christian era, his observation remained unheeded for twenty centuries. During the long years of the Roman wars, and later, when the Goths and Vandals were overrunning Europe, spreading terror and anarchy in their path, and precipitating the dark age of ignorance and superstition, we can well imagine that the trivial thought of catching feathers with a piece of amber would have no attractions for men, and so we find that it was not until the beginning of the seventeenth century that any further notice was taken of Thales' Amber Spirit. Nevertheless, the little

seed of investigation which had lain buried for so many centuries was neither dead nor wholly forgotten, and from this tiny grain of knowledge has grown the vast tree whose roots reach out to the ends of the earth, and under whose wide-spreading branches thousands of working men now find their daily occupation and sustenance. It is my design to trace out, very rapidly, and of necessity very imperfectly, the gradual development of this germ, to follow the ramifications of its roots, to show the luxuriance of its foliage, and finally to point out a few of its most promising blossoms, some of which are just budding into fruit, while others, though they may seem to flourish for awhile, are doubtless doomed to fall to untimely decay.

The science of Electricity is now passing through a critical period of its development, analogous to that which its sister sciences, heat and light, experienced some years ago, when a famous coterie of eminent investigators (prominent among whom was our countryman, Benjamin Thomson, afterwards Count Rumford) dissected the chrysalis, cleared away the cobwebs which surrounded it, overturned the corpuscular theory, and, by a magnificent series of experiments, proved that heat and light are not material substances, which may be squeezed out of a body, like water from a sponge, but that they are merely "modes of motion" of little molecules of matter.

There are in effect two theories of electricity now extant; the older one, although actually repudiated by practical electricians, still lingers in our text-books, and is, unfortunately, still taught in many of our schools. The other is the new science which has been the outcome of the labors of such men as Sir Wm. Thomson, Professor Maxwell, Dr. Siemens and many others of eminence and ability.

The first of these two sciences, which must, we hope, soon be eradicated from our school curriculum, is founded on the theory that electricity is a fluid, or that there are two fluids, commonly called positive and negative or vitreous and resinous. We must discard the old notion of electric fluids or currents flowing along a wire, as water flows through a pipe, and learn to realize that there is no passage of any material substance whatever when the circuit is closed on a wire in Philadelphia and the click is heard almost instantly in the receiving instrument in New York.

We no longer believe, as did our ancestors, that there is any transfer of material substance along the beams of light and heat which proceed from the sun to the earth. We know that there is simply a transfer

of motion from particle to particle of the intervening, highly attenuated medium, called for the want of a better name, the "luminiferous ether."

If you cast a stone into a pond and watch the ripples radiating outwards, growing larger and larger, until they strike the opposite shore, you do not imagine that the actual particles of water which were displaced by the stone have traveled to the other side of the pond. You know, on the contrary, that they have given up their motion to their nearest neighbors and these again have passed the impulse to their neighbors, and so on until there has been a transfer of motion through the whole of the water and the wave strikes the distant shore. So we believe that when a body is "charged with electricity" its molecules are thrown into a new state of vibration, not very different in character, perhaps, from that which shows itself as light in the little filament of carbon, enclosed in a vacuum bulb, which we will cause to become brilliantly incandescent by means of the electric force obtained from the dynamo-machine operated by the engine in the laboratory.*

Let us then once and for all discard the antiquated notion that electricity is a fluid and regard it henceforth as a form of energy or a mode of motion; we will then find that many hitherto vague and confused ideas in regard to its character may be reduced to definite and clear terms and that the most delicate phenomena of electricity may be measured with mathematical accuracy and precision.

Those of us who have gained clear ideas of the nature of matter and its properties will find little difficulty in conceiving the possibility of a vibration of molecules, under electrical excitation, or rather of such vibration *causing* electrical excitement. We know that the molecules constituting even the most dense solid substances, like lead or platinum, are not in actual contact, but that they are free to move, and, in fact, are constantly and forever vibrating with enormous velocities within certain boundaries. It is even believed that if this molecular motion should stop, "matter, as we know it, would cease to exist."

We know that the mere change in temperature of a few degrees is sufficient to visibly alter the length of a bar of iron or other metal, and we can easily realize that, as the temperature of all bodies is incessantly changing, its molecules are forever in motion from this disturb-

* The lecture room was illuminated with Edison and Maxim incandescent lights.

ing cause alone. We know that the change in condition of a substance from the solid to liquid and thence to the gaseous form is a visible expression of the increased motion of its molecules under the influence of heat vibration. We know that sound, heat and light, have all been resolved into "modes of motion," and now we believe that electricity also is henceforth to be included in the study of the laws of motion. Thus we see that the most widely separated phenomena and the most complex of nature's operations emanate from one common cause, showing a "unity in diversity" which is in itself a strong and logical argument in favor of the new theory.

There is one point which investigators in this field of research too often fail to fully recognize, viz.: that you can no more create electricity from nothing than you can create steam-power without the expenditure of fuel; for, although the various forces of nature are mutually interchangeable, they are so nicely balanced and controlled by unchanging law, that man with all his ingenuity cannot add to, or subtract one tittle from, the sum total of force in the world; the most he can ever hope to do is to utilize these ready-made forces for his special purposes, with the least waste possible.

The theory that electricity is a form of energy, which can only be developed by an equivalent expenditure of work of some kind or other, is quite a modern notion, and as it becomes more fully understood it will tend to eradicate many of the vague ideas and fallacious expectations which now prevail in regard to the future possibilities of utilizing electricity for lighting, heating, driving machinery and countless other useful purposes for which it seems so well adapted.

The general acceptance of the idea that electricity is a form of energy and not a form of matter has been somewhat retarded, hitherto, by the lack of adequate terms in which to express its dicta, for scientists do not coin new standard words as rapidly as the mint coins its new "standard dollars," which are, however, false measures of value, even though they may be of true standard fineness. This difficulty is gradually becoming eliminated, and the obsolete expressions which convey the idea of fluids and currents are giving place to more exact definitions; thus, the word *potential* is used to express the difference between a body in a state of electrical tension and another in its normal condition of molecular equilibrium; it does not commit us to any preconceived theories, and possesses another great merit in that the difference of potential (or electro-motive force, which is an equiva-

lent expression) between two dissimilarly electrified substances may be accurately measured and their comparative values may be stated in terms which we can all understand, and may even be reduced to the ordinary mechanical unit of work, the foot-pound.

There are other terms, which have been devised, to express the units of intensity, resistance, etc., with which the student must familiarize himself; their elucidation does not come within the legitimate scope of a "popular lecture," which should aim, first, to awaken interest in the subject of which it treats, and then to point the way in which it should be pursued to its ultimate goal. The student of electricity will find a permanent investment for his intellectual capital, never failing in interest, for the fund of knowledge is growing larger day by day.

In view of the modern developments in electrical science only a foolish man would venture to define the boundaries of its future progress, for if we allow our imagination the smallest liberty in the contemplation of such subjects we are sure to be almost startled at the vast possibilities for practical and useful applications of this force which suggest themselves; and yet, when we consider the actual accomplishments of the searchers in this field during the past few years, the most daring flights of fancy seem hardly more than natural sequels to events which have already outstripped all calculation.

It is not unlikely that some of my hearers may remember the years when Morse was wearily striving to obtain a small grant of money from an unwilling Congress, to enable him to lay his experimental telegraph line from Washington to Baltimore. He was derided as a crazy visionary, and Congress was ironically advised, by jeering wiseacres, to appropriate money from the public coffers to project a telegraph line to "the man in the moon." Most of us, doubtless, well remember the time, not very far distant, when the idea of an Atlantic cable was generally regarded as an impracticable and absurd scheme, yet there are now "more than seventy thousand miles of sub-marine cable," and the overland wires threading the earth to-day are long enough, if they should be stretched in a straight line, to reach our satellite!

The present magnitude of the telegraph business is a favorite theme for writers on these subjects, and has been well set forth by Mr. Preece in his lecture on the "Recent Wonders of Electricity." It is matter of history that on the day of President Lincoln's funeral no less than

seventy thousand words were transmitted from Washington to New York in the short time of six hours and a half, and this was before the use of the quadruplex system, by means of which four messages are now sent over one wire, in different directions, at the same time, and it was also prior to the invention of the automatic system, which has increased the speed of transmitting words more than one hundredfold.

The telephone, in its practical form, is not yet six years old, and yet there is scarcely a business community of any importance in this country or in Europe to which it is a stranger.

The electric light is no longer a scientific curiosity, and the manufacture of the plant used in its production has grown into a large industry, giving employment to hundreds of workingmen, and representing millions of dollars capital invested.

The art of the electro-plater is another vast industry, and the statistics of the amount of gold and silver annually consumed in the process of gilding and silvering the baser metals seem almost incredible, especially when we reflect that a single grain of precious metal will cover several square feet of surface.

The admirable "block system" of operating railroad trains, which has greatly reduced the danger of accidents from collision, calls in the aid of this force, or rather depends upon it for its very existence, and even trains themselves have been propelled in Europe for several months past by this force alone. The idea of employing electricity as a motive power for machinery is by no means a novelty, but it has assumed new importance in the light of the recent improved methods of developing and utilizing the force economically.

It is a stupendous thought that our great natural curiosity, Niagara, is freely offering to our use its mighty arm, which is strong enough to turn every loom, operate every machine shop or other manufactory throughout this broad land, and that this may be accomplished by the intervention of means which we already possess of converting the headlong force of the cataract into the quieter channel of dynamical electricity, or, as we might otherwise say, *by changing its mass motion into molecular motion.* The calculations made by Sir Wm. Thomson, Dr. Siemens and other eminent scientists, show that this is no mere poetical fancy or impracticable idea; it is certainly quite within the bounds of rational discussion, if not of actual possibility, at the present time. It has been shown that a copper cable of no unwieldy dimensions would carry one thousand horse-power of electrical energy a distance

of one hundred miles without a very enormous loss, and it is even predicted that the time will come when our factories will be operated during the day, and our shops and houses illuminated at night, by the giant power of Niagara or some other less water-fall nearer home.

It would seem a curious and beneficent provision of nature that when the coal and wood, with which we are as yet well supplied, shall have become comparatively scarce and dear, the future race of men may find their substitute in water, not merely as a source of mechanical power, but also of light and heat.

It may be that our descendants will look back with curiosity to the time when their ancestors discussed with caution the possibility of thus utilizing the waste forces of nature, and they may well wonder at our extravagance in consuming black diamonds in our furnaces in order to obtain therefrom a mere modicum of their stored energy in the form of mechanical power.

As an ever watchful detective against our common enemies, fire and thieves, this agency has proved its fidelity time and again, never compounding with felons, and, if properly attended to, never failing to perform its duty.

By the simple addition to the ordinary ship's compass of two platinum pins, forming the terminals of a wire connected with a little battery and a call-bell, the captain of the vessel may retire to rest in security, knowing that if the man at the wheel allows the ship to wear away more than the fixed allowance the little bell will sound its note of warning in the cabin or stateroom; it is even possible to make the arrangement automatic, so that the same controlling force shall open steam valves which operate the mechanism of the rudder, and so the vessel may be kept on one undeviating course without the further intervention of human agency. The same principle has been applied to steam and water gauges, to sound a timely warning in the office of the large manufacturer when the pressure of steam in the boiler exceeds a certain limit or the level of water falls below a safe point.

The doctor and surgeon have found electricity a most valuable auxiliary in their efforts to alleviate human suffering, and new fields of usefulness in this direction are almost daily opened up to the profession.

In the physicist's sanctum electricity reigns supreme, for it is equally adapted to perform the coarsest work and to assist in the most refined investigations.

At the various meteorological stations throughout the country, the finger of electricity is at work, day and night, recording the hourly and even momentary changes of atmospheric conditions, and the same agent transfers these records to the central bureau in Washington in order that the mariner and the farmer may be forewarned of the approach of tornadoes, rain-storms or biting frost.

At the government arsenal may be seen a beautiful apparatus for recording, by a little spark of electricity, the velocity of projectiles, thus affording a means of measuring the explosive force of different samples of gunpowder. The whole distance the bullet is allowed to travel is only a few feet and the time consumed in its flight is inappreciable to the ordinary perception, yet the record made by the spark (which passes from a vibrating tuning fork to a cylinder of metal coated with lamp-black, revolving at a known speed), tells at a glance the exact time consumed, which is so infinitesimal that its expression in decimal fractions of a second requires a prefix of several ciphers.

At a recent scientific entertainment in London luscious fruits, which were grown by the aid of the electric light, were served to the guests. I dare say, many of you have read with interest Dr. Siemens' account of his experiments in electrical horticulture, the practical possibilities of which are, no doubt, more apparent to the inhabitants of that land of perpetual fog than to our more fortunate selves, where the sun is so generous of his beams and so constantly "shines free for all."

The astronomer, whose gaze is fixed on the heavenly bodies, does not scorn to avail himself of terrestrial electricity, and he, too, has found this force an invaluable aid in his most abstruse researches.

Applying the principle of varying resistance of metals at different temperatures to the passage of electricity he has recently been enabled to construct an apparatus for measuring the heat of the stars,* a sort of celestial thermometer "which will promptly indicate a change of less than one fifty-thousandth of one degree Fahrenheit, and will even measure these extremely minute amounts of heat and compare their differences with each other, though the whole quantity involved would produce no change whatever in the most sensitive thermometer."

These are but a very few of the useful applications of this ubiquitous agent, which seems to be the only one of man's possessions that he can employ in two places at practically the same time. To indicate the various other directions in which electricity may be utilized in the

* Professor Langley's *Bolometer*.

future would require both a vivid imagination and a careful sense of discrimination, and would occupy far more time than we have to devote to such speculations. We can only allude, in conclusion, to the probability of telegraphing without wires, which has already been done experimentally, and to the more remote possibility of transmitting the power of vision to a distance through the peculiar electrical properties of selenium when acted on by light.

Whether these beautiful experiments, which are the very quintessence of refinement in physical research, may produce practical results or not, they will undoubtedly serve as indicators to future generations of the intellectual and scientific attainments of the human mind in our day, and each new step forward enlarges the scope of our mental vision and smoothes the path for those who are to come after us.

As we stand on our vantage ground to-night and look back over these recently explored regions, we have reason to feel proud of all that has been accomplished and to rejoice that we are living in an age of such activity and progress in useful and ennobling scientific pursuits.*

Pulverizing Rocks by Dynamite.—Major Lauer claims that his method of pulverizing rocks in the beds of rivers, by exploding dynamite on their surface, leaves them in a condition to be removed by the current. When the cartridges are inserted in drill holes, the rock is broken into large fragments, which must be removed mechanically and often at great cost.—*Ann. des P. et Chauss.* C.

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* The technical portion of the lecture, which is not reported herein, was illustrated with apparatus, both of historical interest and of recent invention. In the former list was Dr. Benjamin Franklin's frictional electrical machine, by means of which he sent electric flashes across the Delaware river, between Philadelphia and New Jersey, through a submerged cable, one hundred years before the invention of the Morse Telegraph.

An original working model of Bains' electro-chemical telegraph; also, an original Morse apparatus, all of which are preserved in the museum of the Franklin Institute.

In the latter category were induction coils, Geissler & Crookes tubes, Toepler-Holtz machines, etc., contributed by Messrs. Queen & Co.

A Brush dynamo-machine, operated by a six-horse power engine which supplied arc and incandescent lights, the Maxim lamps being contributed by the Company and the Edison lights by the Baldwin Locomotive works, where they have been in practical operation for some months past.

AN ESSAY ON MECHANICS AND THE PROGRESS OF MECHANICAL SCIENCE—1824 TO 1882.

By FREDERICK FRALEY, LL.D.

One of the Original Members of the Franklin Institute and President of the American Philosophical Society.

[A Paper read by title at the Meeting of the American Society of Mechanical Engineers, Philadelphia, April, 1882.]

With an introduction by COLEMAN SELLERS, M.E., Passed Vice President of the American Society of Mechanical Engineers.

[A meeting of the American Society of Mechanical Engineers in the lecture room of the Franklin Institute in Philadelphia, suggested to President Thurston the desirability of a paper on the part played by the Franklin Institute in the progress of the mechanic arts in America, and he so advised the Local Committee. It happens that the present Treasurer of the Franklin Institute was one of those who organized the Society in the year 1824, and he has been not only a member ever since, but he has at almost all times been engaged in the management of the Institution. It is natural to turn to one who has taken part in the active work of the Institute for fifty-eight years for information, so it comes that the writer asked his friend, Frederick Fraley, LL.D., to prepare the paper herewith presented. The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, has, through its more than half a century of existence, done much to earn its full title. While mechanic institutes started at the same time have long since passed out of existence, this Institute, founded on the broad basis of uniting all who are to give and obtain instruction, has grown and prospered. Its prosperity, and the work it has done, afford a useful lesson. It has never confined its membership to mechanics only, but while its constitution provides that its Board of Management shall hold a majority of manufacturers, it draws to itself all who are in any way interested in the progress of the Mechanic Arts, and this bringing together of men of varied interests on the common ground of seeking for information, has had the best possible result. Mr. Fraley has repeatedly told the writer that he owes to the Franklin Institute the greater part of his education, and much of his success in life. In asking for this contribution to the history of a scientific society, it is

hoped that the information given may be of use, not only to kindred societies, but even to one that is more limited in its range of membership than is the case with the Franklin Institute.]

I have been a member of the Franklin Institute since its organization in 1824, and this is the only right I have to present this paper for your present session.

When I recall my early remembrance of the mechanic arts in this city in the days of my youth, and compare them with what I see around me now, it is difficult to realize the change or to make any satisfactory comparisons. What was true of the condition of mechanical science in this city at the beginning of the present century was more so, of every other part of the United States, and comparatively so, of the continent of Europe and of the island of Great Britain. The active inventive genius of the English and French people in the latter part of the 18th century was beginning to develop the germs of the great machines that have since been perfected, and have, it may almost be said, revolutionized the world. The laws of motion and the application of the mechanical powers had become to some extent known, and chemistry was rising in importance and aiding in carrying on the processes which were to subdue the rude natural materials which were to supply the mechanic with the means for carrying on his labors.

What was needed was the establishment of some kind of school that should bring together intelligent men of different professions and occupations, and by mutual support and study increase the amount of useful knowledge, and divide and distribute it to form new combinations and to make the growing wealth of such acquisitions available for the common good. It was for these ends that the Institute was founded, and its history truly records the growth, advancement and present state of mechanical science in the world. As it was the first really educational mechanics' association in the United States, it has continued to hold its rank as "*primus inter pares.*"

Let us consider for a moment with what we had to deal in its origin. There were a few small and isolated workshops in which mechanical trades were carried on with rude and imperfect tools, and perfection depended more on the strength and skill of the hand of the artisan and on the acuteness of his eye, than on any clear mental perception of what he was doing or that the doing of it could be reduced to anything approaching scientific rules.

I recollect my visits to some of the well-known work-shops of those days, and have seen Patrick Lyon striking vigorous blows on his anvil, Oliver Evans in his foundry, Jacob Perkins in his fire engine manufactory, and the Messrs. Sellers in their then wonder-working wire works, turning out the marvelous hand and machine cards. It was indeed a great privilege to be permitted to visit those establishments, for they were the pride of their proprietors, and were not to be entered by all with impunity.

But with the establishment of the Institute came a new phase of these things. There had for some years been a sort of mechanics' club, which zealously guarded additions to its membership, and was so much attached to ancient mysteries, that it mercilessly black-balled all who attempted entrance by the shibboleth of modern ideas.

So it happened that Samuel V. Merrick was excluded from this venerable, close guild, and he resolved to form an institution on a more liberal basis and with broader views, and he joined to himself a few congenial spirits, who went manfully to work and called a public meeting of Philadelphia citizens, which was largely attended, and which enthusiastically adopted the plans of the founders, and gave us the great institution in whose Hall you are holding your present meeting.

True it is that Benjamin Franklin founded in Philadelphia, in the year 1743, the American Philosophical Society for the promotion of useful knowledge, but mechanical knowledge in that day did not hold the place it now does.

While Franklin followed a mechanical trade and did much handicraft work to make his printing attractive and profitable, he soared to higher heights and became philosopher, statesman and political economist, by which he earned his great and glorious name.

Philadelphia has always been distinguished for the beauty and excellence of its mechanical productions.

In the earlier part of the present century she was the point of attraction for purchasers from all parts of the United States.

It was therefore eminently fitting that a great mechanics' educational institution should be established in that city.

The plans for it were comprehensive and struck down to the very roots of what was needed.

It took hold of the grown and skillful men of all trades, blended them with merchants, lawyers and scientists, put them all in personal

and friendly contact for the communication and diffusion of all they knew, and then made provision for the education of the young in a high school, to be characterized by the teaching of what would be useful in practical life.

It established the first regular school in the United States for instruction in mechanical drawing, and has kept it in successful operation for more than fifty years. In the first year of its existence it had courses of lectures on mechanics, chemistry, architecture, natural philosophy, and volunteer lectures on particular arts and trades. These lectures were attended by numerous classes, and made a great impression on the public, which increased the power and promoted the success of the Institute. This success gave it courage to hold an exhibition of American manufactures, the first held in the United States; and the specimens of American skill then presented were numerous, well made and indicated a good basis on which future progress and perfection could be built up. Such exhibitions have been continued at convenient intervals, and have marked the march onward of mechanical skill. By the division of the leading members into standing committees on all the principal objects of the Institute, and by the regular meetings, the whole machinery of instruction was put in motion, and the results were soon apparent. It gathered a valuable library and cabinets of models, minerals and manufactured products, and thus soon became an Institute of Technology of the first rank, and that rank it continues to maintain at this day. It seems to be like the fable of the eagle continually renewing its youth, and as the old veterans have fallen from the ranks, the young and vigorous have filled up vacant places with enlarged knowledge and fired with the same confidence and hope.

Another aid given by the Institute to the development of mechanical science is found in its JOURNAL. This publication has been continued monthly for more than half a century. It contains a full *resumé* of American patents up to the period when the Patent Office commenced the publication of its reports. It contains, besides, many original essays and copious republications of articles on mechanics from foreign journals. By exchanges, it has largely contributed to build up the library which has now a large store of wealth of technological knowledge.

In the way of original research the Institute can point with pride to its investigations of the value of water as a motive power; of the

causes of explosion of steam boilers, of the strength of materials, of dynamo-electric machines, and to its examinations and reports upon many hundreds of new inventions.

These have brought into permanent notice many of the active members, who unselfishly devoted themselves to the elucidation and dissemination of the great truths which adorn the fields in which they labored. To name them all would be difficult indeed, for their number is not small. Prominent among them, however, are Samuel V. Merrick, William H. Keating, Robert M. Patterson, Matthias W. Baldwin, Rufus Tyler, Benjamin Reeves, Isaiah Lukens, Franklin Peale, Asa Whitney, John C. Cresson, William Sellers, Joseph Saxton. One of the early chiefs was Alexander Dallas Bache, who closed his life of devotion to science as superintendent of the United States Coast Survey, a work which gave full play to the highest forms of accurate and useful applications of mathematical and mechanical knowledge.

In this connection, also, I must strive to pay just tribute to the merits and zeal of its professors, among whom we find in its early days, R. M. Patterson, William H. Keating, William Strickland, Franklin Bache, John K. Mitchell, Walter R. Johnson, John C. Cresson, James B. Rogers, and John F. Frazer. Their successors are numerous and worthy, and they in the present days are upholding the honor and sustaining the reputation of this mother of mechanical institutes of our country. As she was the first of these really educational institutions, the model which she presented has been closely followed, and the benefits which she gave to the mechanics of Philadelphia are now largely shared by the craftsmen in all parts of our widely extended territories, by the labors which such kindred institutions have fully and freely bestowed.

My object in the preparation of this paper was to attempt to show by the history of the Institute, some illustration of the progress of mechanical science for the last sixty years, and to show by the gleanings I have made from this vast field, amid the active labors of a different line of life, the impressions made upon my mind by the truly marvelous triumphs of mechanical skill, which have claimed my admiration and remembrance. If I shall add an hour of pleasure to your meeting I shall be amply repaid for its preparation.

I cannot close it, however, without attempting to bring before you, in contrast, what I saw of machinery and its progress in my youth,

and what I see now. I shall refer first to the supply of water to the city of Philadelphia.

Then she was just emerging from the use of wells and hand-pumps, and the rude steam engines placed near the Schuylkill river at Chestnut street and at the base of the marble building in the Centre Square at Market and Broad streets, and the modest basin eighty feet at its summit, and sixty feet in diameter, were the wonder and boast of the citizens. The pipes for the distribution of the water were wooden logs bored by hand, and it was not until after the establishment of the Institute that iron pipes were cast in this country. A few had been imported from England, and this fact became a political war-cry, and nearly revolutionized the city government. About the year 1822 the water-power works were established at Fairmount, a transfer of the steam-power having previously been made to that point, a large Boulton & Watt engine, having taken the place of the original engines. The Boulton & Watt engine was a beautiful piece of work, and marked a well-defined phase in mechanical engineering. For a short time by its side worked a high pressure engine of great simplicity and with few parts, invented and constructed by Oliver Evans, the great American mechanic, who is probably the inventor of the use of steam under high pressure, and who deserves a high place in the pantheon of inventors. Recollect that then no other large city in the United States was supplied with water by machinery, and that the representatives of city corporations came to study and imitate our example. Now every large city boasts of its water supply arrangements, and the steam and water powers exhibit the perfection which study and experience give. Compare the locomotive engine of the present day with the embryo of Oliver Evans, or the machine of Blenkinsop, or the English machines of Stephenson, or the first one of Baldwin, with those which are now daily turned out of the hundreds of the great workshops of the world, and notably those of our own country, and you will again realize the progress of your special science.

Look at the manifestations of the same progress from the rude spinning jennies and mules of Arkwright and Crompton, to the contents of a modern cotton or woolen mill, and marvel at the mechanical fingers which spin and weave the massive sail cloth or carpet, and the gossamers which clothe the queens of kingdoms and of fashion.

Look at the machines and tools of precision, and see how they have contributed to bring about so much perfection.

In this connection, also, the introduction of standard sizes and uniformity in the several parts of machines have tended to great economy and practical usefulness.

How much has been gained by the adoption of the United States standard for screw threads, for which we are indebted in a large degree to the ingenuity and experience of Mr. William Sellers. The stand taken by the Institute to prevent a forced adoption of the French metric system has been of great use in guarding us from a violent and unnecessary revolution in the weights and measures of our country. These are so identified with all our measurements, and the welfare and protection of society and property that to disturb them seems to me to be as criminal as the burning of the great library at Alexandria.

Upon such a survey of the progress of mechanical science as it has fallen under my observation and study, I feel that the men of this century have well performed their duty, but they must keep their hands to the plough and not be content with what has been accomplished. They must cherish the spirit of brotherhood, be ready and willing to communicate and spread all useful knowledge. They must aid in keeping up the great educational institutions of the country, especially in their scientific and technical departments, and so give to the present and coming generations the advantages and accumulations of all the wealth of knowledge which has been obtained by the labors of genius and perseverance, and provide more abundantly for their increase.

Telegraphing in Mid-Ocean.—M. Menuisier proposes to attach to the submarine cables, at distances which are about equivalent to a day's sail, supplementary cables reaching to the surface of the water and sustained by luminous buoys. A ship, in passing near the buoy, could put the wires of its apparatus in communication, one with the wire of the buoy, the other with the buoy itself, which would serve as a ground wire. The circuit would thus be completed and the buoys being all numbered, communication could be immediately established with the central station. The inventor believes that he has provided against the danger of breaking the cables by tempests and all other objections that are likely to be urged, and he has satisfied able navigators who have examined his plans, that they would be likely to succeed.—*Chron. Industr.* C.

DEVICE FOR INCREASING THE DYNAMIC EFFECT OF THE PULSATIONS OF DIAPHRAGMS AND THE LIKE.

By WM. B. COOPER.*

Abstract of remarks made at the stated Meeting of the Franklin Institute, April 26, 1882.

Within the past few years the impact of sounds acting either upon diaphragms or other sounding bodies rigidly connected with other similar bodies at a distance, or first converted into galvanic impulses, and then reconverted at a distant station into sound waves, have come to play so large a part in the mechanism of our civilization that any invention promising to enlarge the effectiveness and usefulness of these devices naturally attracts attention; this fact has induced me, in compliance with request, to briefly set forth a device of mine having as its principle the augmentation of the above-mentioned comparatively feeble impulses, by adding to them, through the agency of a coefficient of friction, an increment derived from an auxiliary power.

When a cord is passed over a revolving pulley it is well known that there is a pull upon one side proportioned to the character of the surfaces in contact and the pressure upon them; this pull is due to the friction of the surfaces upon each other and increases approximately (if not exactly) in the same ratio as the pressure; now, if the pulley is loose upon the shaft and we draw upon a cord passing over it we have the same force exerted at the other end of the cord minus the friction at the shaft; if, however, the pulley is attached to the shaft and is rotating towards the end drawn upon, then the result at the other end will be the force applied, plus the amount derived from the friction upon the surface of the pulley. This is the principle of my device.* To one end of a wire or band I attach a diaphragm or other pulsating body and then give a half turn or several turns around a drum or pulley; to the other end may be attached a lever having a point adapted to the indentation of sheet-metal passed under it. In this form I have termed it the "Phonodynamograph," and my experiments have already resulted in embossing brass of the thickness of writing-paper by the impact of the voice upon a diaphragm of the

* Mr. Cooper exhibited a model illustrating the principle of his invention.

size used in the phonograph. The increased dynamic effect, however, may be used in various ways; for example, it may be made to operate a stouter diaphragm, or even an armature of some weight, to and from the poles of a magnet, as in the telephone, and thereby produce more powerful galvanic impulses and consequently a louder tone, and the diaphragm, or an armature at the receiving station, by this device, may be made by means of a lever and a spring, to create pulsations of greater amplitude in a second diaphragm and thus increase the sound; this last may be accomplished in another way which the limits assigned for this article will not permit me to describe.

INFLUENCE OF PULLEY DIAMETER ON THE DRIVING POWER OF FLAT BELTS.

By ROBERT GRIMSHAW.

[Abstract of a paper read at a meeting of the Franklin Institute held April 26, 1882.]

Most of the experiments reported have appeared to show that the diameter of the pulley has no influence on the coefficient of friction or the driving power of belts. Dr. Grimshaw described some experiments in which belts were made to slide over fixed pulleys, and announced as a result that the thicker the belt the greater the influence of pulley diameter upon its driving power, and that the smaller the pulley the greater the loss of actual contact surface (proportional to the size of pulleys) due to the ridges formed in thick and stiff belts that are sharply bent. The speaker claimed that nearly 1000 experiments made by him warranted the rejection of Morin's law.

The following tests made with a single "fulled" leather (partly tanned) belt made by Schultz Belting Company, St. Louis, are given as examples of tests made by Dr. Grimshaw's assistant, Mr. John E. Hilleary, on the day of the meeting. The pulleys were turned cast-iron, little worn and but slightly crowning, being Cresson's standard.

The first column gives half the weight of the belt; the second column, the weights added; the third, T_2, the tension on the slacker of the two sides; the fourth column, the weight added to cause slipping; the fifth, T_1, the weight on the taut end; the sixth, the grip or difference in tensions; the seventh, the ratio of T_1 to T_2; the eighth, for

convenience of reference, the natural logarithms of the ratios; and the last column, the coefficient of friction according to Morin's formula,

$$C = \cdot 733 \log. \frac{T_1}{T_2}.$$

The averages of the ratios and of the coefficients of friction at different tensions, are given for each pulley. It shows in this case a difference in the coefficient of friction, of 24·06 per cent. in favor of the larger pulley.

Single Fulled Leather Belt, 4 inches wide, 180° contact.

	½ Weight of Belt—lbs.	Added Tension. lbs.	Total Tension Light End—lbs. T_2.	Weight added. Taut end—lbs.	Total Weight. Heavy End. T_1.	Grip—lbs.	Ratio, $\frac{T_1}{T_2}$	Log. Ratio $\frac{T_1}{T_2}$	Coef. friction $= \cdot 733 \log. \frac{T_1}{T_2}$
36-inch Pulley.	1·50	5	6·50	12·	13·50	7·	2·072	0·316390	·2319
	1·50	10	11·50	22·	23·50	12·	2·043	0·310268	·2274
	1·50	20	21·50	43·	44·50	23·	2·116	0·325516	·2383
	1·50	40	41·50	88·81	90·31	48·81	2·176	0·337659	·2475
	1·50	60	61·50	126·81	128·31	66·81	2·09	0·320146	·2346
						Av.	2·099		·2359
18-inch Pulley.	1·50	5	6·50	10·87	12·37	5·87	1·903	0·279439	·2048
	1·50	10	11·50	20·	21·50	10·	1·869	0·261609	·1917
	1·50	20	21·50	37·	38·50	17·	1·79	0·252853	·1853
	1·50	40	41·50	81·81	83·31	41·48	2·01	0·301247	·2208
	1·50	60	61·50	110·81	112·31	50·80	1·81	0·257679	·1888
						Av.	1·874		·1982

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

AN IMPROVED MERCURY PRESSURE-GAUGE, which employs the Bourdon spring, is designed to obviate the trouble arising from the tendency of the tube connecting the boiler with the gauge, to become clogged by the lodging of sediment within, by the rusting of the pipe, or by the freezing of water condensed therein. The same trouble is likely to arise in the passages of the Bourdon spring. It is essential, therefore, that the Bourdon spring be connected with the boiler in such a manner that it can be ascertained at any moment whether the steam has free passage therein and free access to the spring; and also that the danger of freezing of the condensed steam is made as slight as possible. The improvement consists in combining with the steam supply pipe, a pipe connecting it with the passages of the Bourdon spring and adapted to contain mercury or other pressure-transmitting medium, and upon which the steam is brought in direct contact. A passage communicating with the outer air extends from the end of the steam passage, and has a suitable cock or valve for opening and closing the same.

A NOVEL DEVICE FOR UNDERGROUND ELECTRIC COMMUNICATION comprises a conduit or main, laid beneath the road-bed in the street, with service nipples at desired points in the conduit. These nipples are provided with a laterally upwardly extending chamber, the access or opening of which extends under the curb and up to a level on the sidewalk. The wires pass in coils over cleats in the mouths of said openings where they can be conveniently tapped when desired.

A NOVEL RECEIVER FOR TELEPHONES is provided with a diaphragm made of cork. This diaphragm has a central button of carbon attached to its centre. A reduced flexible extension of the magnet core is in contact with the piece of carbon. The molecular vibrations of the magnet are communicated to the carbon and through the same to the diaphragm.

AN IMPROVED DEVICE FOR LUBRICATING CAR-AXLES consists of a brass or bearing provided with a chamber or recess on its lower side, or that next the axle. A passage-way is provided between said chamber and a pump, which is operated by the vertical vibratory

motion of the axle-box, which tends to lift oil to the chamber. This pumping device consists simply of a vertical tube, having the end which projects into the oil reservoir made flaring and provided with a check-valve opening upwardly. The oil will be further assisted to rise in the tube by the partial vacuum created in the said chamber by the revolution of the axle.

A NEW ADJUSTABLE PISTON comprises two parts, the meeting ends of which are cylindrical in form. One of the ends is arranged to move longitudinally in a recess in the other part, and has a screw-spindle taking a bearing on said part. A screw-threaded locking-sleeve serves to lock the two parts together.

A RECENT AND IMPORTANT IMPROVEMENT in "individual call" systems of telephone alarms is announced. It comprises a clock mechanism at the central station which is normally at rest. It carries a revolving electrode. Another electrode, adjustable by hand, is arranged concentric with the axis which carries the revolving one. The catch, which holds the clockwork normally at rest, carries a contact point whereby the battery-current can be thrown upon the line momentarily when the catch is operated. Each subscriber's station has a clock mechanism, an electro-magnet, and armature arranged in the main circuit for controlling the clock-work. A grounding or branch circuit is used. Two electrodes are employed, one being a stationary arm and the other revolved by the clock-work. A spring-impelled train of gears and an electro-magnet and armature are arranged in said grounding circuit for releasing the alarm. The revolving arm-electrodes upon being released (the central station by its catch and the subscriber's station through its magnet in the main line) by a single impulse generated upon the main line, will each rotate synchronously for one revolution, during which that subscriber's station, and that only, whose stationary electrode lies in the same direction as that to which the adjustable electrode of the central station has been set, will have its ground-wire circuit closed and the armature and magnet therein attracted, thereby releasing the spring impelled alarm.

F. B. BROCK.

Washington, D. C., May 12, 1882.

Causes of Magnetic Variation.—F. Folie discusses the hypothesis, which is accepted by many geologists, that the earth is composed of a solid crust, together with a mass, more or less fluid, beneath the crust. Hopkins had previously calculated the precession and nutation which would result from a fluid nucleus, but his conclusions were not satisfactory, and Folie gives new reasons for rejecting them. He thinks that the crust would partake, to some extent, of the disturbances of the interior, and that the only way in which the exact latitude of a place could be found would be by taking observations when there is no disturbance by nutation, or by distributing the observations equally over the whole period of nutation. He further supposes that if the solid shell of the globe oscillates about the fluid nucleus, the friction, which results from the pressure of the nucleus upon its envelope during this movement, should constantly engender a great quantity of electricity, which may be one of the principal causes of terrestrial magnetism. The gradual cooling of the interior ought, according to this hypothesis, to be shown by a diminution of the constant of nutation, and a like diminution of magnetic intensity.—*Bull. de la Soc. Roy. de Belge.* C.

Electric Torsion.—Hughes has arrived at the following conclusions: 1. An electric current polarizes its conductor and the molecular magnetism can be converted into an electric current by a simple torsion of the conductor. 2. It is only by the rotation of its molecular polarity that an electric current is produced in consequence of torsion. 3. The passage of a current through an iron or steel wire is spiral. 4. The direction of the spiral depends upon the kind of current and on the magnetic polarity of the wire. 5. A natural magnet can be arranged with spiral molecular polarities, and consequently electric currents of opposite kinds may both produce a like spiral. 6. Torsion of the polarized molecules may be produced by a forcible transverse or longitudinal stretching. 7. The rotation, or the movement of molecules, produces audible sounds. 8. These sounds may be increased or diminished, or even destroyed, by the same means which produce molecular rotation. 9. The same effects having been obtained by three different methods, it cannot be said that they are due to a simple change or weakening of polarities. 10. Heat, magnetism, continuous electrical currents, mechanical stretching, vibrations, all exercise a marked influence upon this class of effects.—*La Lum. Electr.* C.

Sensible Evidence of the Roundness of the Earth.—In a late session of the Helvetic Society of Natural Sciences, Prof. Dufour spoke of the change which images that are produced upon a great expanse of water undergo, in consequence of the roundness of the earth. If the luminous ray from an object strikes a tranquil lake, in a nearly horizontal direction, the image is made upon a convex surface and appears smaller than the object itself. Prof. Dufour arrived at these conclusions by calculation, but he supposed that they could never be verified on account of the difficulty of finding a lake sufficiently calm over a broad extent of surface. His friend, M. Forel, however, informed him that he had seen such images in the lake of Geneva, and that they appeared exactly as the calculation had indicated. Prof. Dufour subsequently found that the days upon which such observations are possible are by no means uncommon, but the images can often be seen on lake Leman, especially if one has a spy-glass at his disposal. After having looked for a moment, the roundness of the earth becomes visible as plainly as that of a bowl that is held in one's hand.—*Les Mondes.* C.

Identity of Spectral Rays in Different Elements.—The question of identity of spectral rays is one of great interest; as it is very improbable that a simple molecule should be capable of taking part in the immense variety of vibrations which are indicated by the complex spectrum of iron or titanium, we may suppose that these substances are formed of heterogeneous molecules and that some of those molecules are common to numerous elements. Moreover, the supposed identity of certain rays has furnished Lockyer with an argument in favor of a simple theory of chemical composition from one or a small number of primitive elements. Angstrom gives seventy lines, as common to two or more substances. Young found that fifty-six out of the whole number are double or triple, seven more doubtful, and only seven appear decidedly simple. Liveing and Dewar find that even the last class are more refrangible in some elements than in others. Hence they draw a conclusion which is opposite to that of Lockyer.—*Ann. de Chim. et de Phys.*

[The well-known experiment of swinging balls suspended from a horizontal cord shows that cyclical vibrations are modified by each member of a harmonic group, so that Lockyer's theory would not be shaken by slight differences of wave length when the same element is combined with different elements.] C.

Viscosity of Gas.—Brooks concludes from his experiments upon the viscosity of gas in a nearly perfect vacuum, that some of the molecules may traverse more than a hundred times the mean distance of their ordinary course, and that they may also acquire a corresponding augmentation of the mean velocity before being stopped by collisions. From some of the phenomena he infers that the gaseous and ultra-gaseous states succeed each other in an insensible manner, so that at a given moment we may be able to perceive, at the same time, the phenomena which are produced by the gas and by the ultra-gas. The experiments of Tresca and Andrews have shown that the same fact is true in the passage between the solid and the liquid, and between the liquid and the gaseous states.—*Ann. de Chim. et de Phys.* C.

Powerful Electric Discharges.—De la Rue and Müller have experimented upon the electric discharge, during the past six years, with a voltaic battery of constant current. It is based upon the Daniell cell, but a solid electrolyte, which is insoluble in water or chloride of silver, replaces the soluble, so that the porous cup can be dispensed with. By a combination of 14,400 united elements in series they have produced a variety of interesting results. If we admit that a cloud, at a very great distance, acts essentially as a simple point, when a flash of lightning is produced, either between two clouds or between a cloud and the earth, the potential which is necessary to produce a flash of a mile's length would require 243 units, equivalent to the combination by the experimenters of about 3,500,000 cells.—*Ann. de Chim. et de Phys.*

Detection of Malic Acid.—Two Italian chemists have found that when a solution containing malic acid is boiled with a few drops of sulphuric acid and a small quantity of bichromate of potash, a strong odor of ripe fruit is developed. They have applied this property to the examination of the precipitate which is produced by chloride of lime, in an alcoholic solution of various organic acids. The precipitate is withdrawn from the solution, decomposed by dilute sulphuric acid, and the filtered liquid is boiled with a small quantity of bichromate of potash. If the liquid remains yellow, succinic acid is indicated and can be detected in the usual way by means of perchloride of iron. If the liquid grows green, but is odorless, there are indications of citric acid. The greenness accompanied by the odor of ripe fruit shows the presence of malic acid.—*Mo. Mag. of Phar.* C.

Electric Light in Building Operations.—The use of the electric light in England for illuminating the works of building and destruction preparatory to rebuilding is increasing. The large machine shop of Messrs. Fowler, in Leeds, having been burnt, the proprietors immediately telegraphed the agents of the Brush machines to furnish their apparatus, in order to help them in clearing away the rubbish during the night. Forty-eight hours after the despatch was received, the Brush lamps were burning over the ruins.—*La Lum. Electr.* C.

CORRESPONDENCE.

What a Patent Grants.

To the Editor of the Journal of the Franklin Institute:

Sir—A paragraph in Mr. Howson's book, noticed on another page, induces attention to an error, popular among patentees, that their patents give them—as on their face they say they do—a "right to make, use and vend" the article or machine described in the patent; the fact that they do no such thing is a fruitful source of trouble, and its discovery furnishes one of the special grounds of complaint against the Patent Office and its administration.

It constantly happens that a man holding a patent which professes to give him this right, assumes that this profession is true, and his surprise and disgust, and not infrequently his loss, are proportionate to the faith which he puts in this assertion, under the seal of one of the highest departments of the government of his country.

In point of fact, the patent does not give him any right whatever—either exclusive or otherwise—either to make, use or vend the thing named; if he did not have an entire and absolute right to do so before he applied for a patent, he has none such by reason of its issue to him. What the patent does grant him is the right to exclude others from making, using or vending the thing covered by the claims of his patent—only that and nothing more—and that is a very different thing from what the patent says, and from what he believes because his patent says it.

There will probably be, before long, some legislation on the subject of patents, and it is submitted that it would be well to have the form of the patent amended, so that it shall say just what it means, and that he who runs may read understandingly.

Of course those who are correctly informed concerning the law of patents know very well what the phrase implies, but patentees as a class are, and of necessity always must be, composed of men who have no knowledge of patent law, and who therefore suppose that the words mean what they say, and so are led to error and brought to loss.

G. MORGAN ELDRIDGE.

Philadelphia, May 8, 1882.

Book Notices.

REISSUED PATENTS: Comments on the Decision of the United States Supreme Court in the case of Miller *vs.* The Bridgeport Brass Company. Practical effects of the Decision and its Warning to Inventors. By H. Howson, Sr. Philadelphia: T. & J. W. Johnson & Co. 1882.

In this volume the author has presented a clear statement of a much troubled and very troublesome question, and has brought plainly before the notice of such of the public as are interested in patents and patented articles the evils which have arisen from the abuse of the privilege of reissue and the inconveniences which are likely to result from a change of law and practice so radical as that which may follow from the decision which forms the text of his discourse. Upon the ground both of the benefits and the injuries likely to accrue the volume is well worthy a careful reading by those concerned in the questions involved, and to those who have the legislative power to sustain the one, and to prevent the other, the suggestions contained in the little book are worthy of consideration.

The right of reissue is a good thing—in many instances affording to an inventor the only possible means of protecting his unquestionable rights—like many other things, good in themselves, however, it has been so much abused that as matters stand at present, or at least as they stood before this decision and some others which clearly foreshadowed it, it is doubtful whether, on the whole, more evil than good has not resulted from it. Some legislation is necessary and will probably grow out of this case, but it will require high skill and rarely good judgment, so to frame it, as to avoid grave injustice in some cases.

The strictures of the author upon the practice of "no patent, no pay," are eminently just, and might fairly have been even more severe.

The evils arising from it can scarcely be overrated—if the subject were once understood by the inventing public they would cease—for the practice itself could no longer exist. A system more demoralizing to the solicitor and destructive to the inventor could scarcely be devised. G. M. E.

THE STUDENTS' GUIDE IN QUANTITATIVE ANALYSIS, intended as an Aid to the Study of Fresenius' System. By H. Carrington Bolton, Ph.D. New York: John Wiley & Sons, 1882.

Many who remember the articles entitled "Schemes of Analyses executed in the School of Mines, Columbia College," contributed several years ago by the author, to the *American Chemist*, will gladly welcome this book. These articles, which the untimely end of the *American Chemist* left in an unfinished state, are now collected and completed in the volume before us. In regard to the purpose of the book we cannot do better than quote from the preface as follows:

"Fresenius' system of instruction in quantitative chemical analysis is placed in the hands of each student on entering the laboratory, but many students are perplexed by the peculiar, though systematic arrangement of this classic work and are at a loss to know how to begin work, what to study and where to find the information appropriate to particular cases. To aid the student in the study of Fresenius' work, and not to displace it, is one of the objects of the 'Student's Guide.'"

The methods given are stated to have been originally selected by Prof. C. F. Chandler, but were modified more or less by his assistants, Mr. Julien, Dr. Schweitzer and the author, Dr. Bolton, who have also introduced some new methods. The descriptions of many of the methods are given with commendable minuteness and clearness. There are also numerous references to other works besides Fresenius', and to articles in recent volumes of the *Chemical News*, etc.

Different chemists will, of course, entertain varied opinions as to the value of the analytical methods selected and described. This is, perhaps, always to be expected of any publication, opinion varying according to individual preferences and other circumstances. It is to be regretted, however, that some of the methods are not given in a form more suitable for strictly technical analysis. Time is a very important element in all such work, and rapidity of execution can very often be combined with sufficient exactness for the particular

object desired by the client. Inasmuch as many students in a laboratory expect afterward to engage in technical work, an appendix or second part giving such methods as are both by rapidity and accuracy especially adapted to technical and professional work of ordinary occurrence would have added greatly to the practical value of the book.

Even where the greatest possible accuracy is quite essential, as for instance in the estimation of phosphorus in iron and steel, the methods given in Fresenius', Crookes', and other works can be materially shortened with advantage and with no apparent loss of accuracy. It is true that phosphorus is a great "bone of contention" among chemists at the present day. It would, therefore, have been best to give in detail several of the different modifications of the molybdate-magnesic method now in use among various technical chemists, that the student might choose that with which he can obtain the best results.

Notwithstanding the variations described by Dr. Gibbs and others, in the composition of the phospho-molybdate precipitate excellent results have been obtained for phosphorus in steels, by a chemist of the writer's acquaintance, by weighing the yellow precipitate directly on a Gooch filter. The percentage of phosphorus in steels is so small that the variations spoken of have no appreciable influence on the result. The case is different, however, with cast iron which carries much phosphorus.

Drown's method for Silicon in iron and steel should have been given a conspicuous place in Dr. Bolton's book, and Ford's method for manganese should have been described as an important technical method. Neither of these recent improvements are even alluded to. The precipitation of zinc, from its ores, by hydrogen sulphide in an acetic acid solution should have been brought forward more prominently. It is not at all necessary to oxidize the zinc sulphide formed and precipitate as carbonate and then convert into oxide, but it may be ignited to oxide directly.

Indirect determination of both alkalies as sulphates is often more convenient than as chlorides.

In lead ores, a subject left untouched, for many purposes the ordinary fire-assay gives results as accurate as is desired by the client, inasmuch as he wishes to know especially what his own furnace will yield on a practical scale. In other cases the lead must be found gravimetrically and is best estimated for technical purposes indirectly

on two separate portions of the ore, weighing as sulphate with the gangue and then treating the one portion with hot ammonic tartrate, made strongly alkaline and subtracting the weight of the residue from the weight of the other portion.

On the subject of water analysis, Dr. Bolton would have done better by describing the albumenoid ammonia method for organic matter, instead of the method of oxidizing volumetrically by permanganate in the old way, which is now almost obsolete in this country. The indications of the latter are of very little value in determining the wholesomeness of drinking water, except in comparative tests of the same river water, like those by Dr. Tidy.

Instead of the analysis of the mineral constituents of water being given, as analysis of potable water, it would have been much more useful in a form adapted to manufacturing purposes. Much less water is required for the sample than is stated; one gallon being ample for a somewhat hard water, and two gallons for a very soft water. Satisfactory analyses have also been made to the writer's knowledge on much less quantities than these. Clarks' soap test is very little used in technical water analysis, except it might be occasionally required in analysis of water for detergent operations. It is of no particular value in ascertaining the effect of the water in producing boiler scale, which is one of the most important and frequently occurring questions in technical water analysis.

In a laboratory guide for technical students it should be stated that of two methods giving equally good results that which requires the simplest, most easily constructed, cheapest or most durable apparatus, is generally to be preferred, and this fact should be indicated in every appropriate case.

The time occupied by an average worker should be appended to each method, or the shortest time with which it has been done with accuracy.

The student should be distinctly informed which technical methods are suitable for very rapid, but only approximate results, and those which are best adapted to obtain greater accuracy with reasonable rapidity of execution.

In the foregoing remarks we do not wish to detract from the value of Dr. Bolton's book as it stands, but merely to indicate how it might be improved very materially in a future edition, so as to give it much wider usefulness. R. H.

THE DRAWING SCHOOL.

The closing exercises of the Drawing School were held on Thursday evening, May 18th, at the Hall of the Institute, in the presence of an interested audience of members, pupils and their friends.

The exercises consisted of the exhibition of the work of the pupils, the reading of the Report of the Principal of the School and a number of addresses appropriate to the occasion.

Mr. Wm. P. Tatham, the President of the Institute, opened the exercises by stating the object of the meeting. He alluded to the solicitude with which the Institute had always fostered and encouraged the art of drawing, by maintaining its drawing school uninterruptedly for a long period of years, and expressed his great gratification at the excellent character of the work of the pupils, which was the best evidence of the thoroughness of the instruction the pupils were receiving, and of the competency of the instructors. The Secretary then read the following report of Mr. William H. Thorne, the Director of the School.

Report of the Director of the Drawing School of the Franklin Institute of Pennsylvania, for the Season of 1881 and 1882.

Notwithstanding that the present organization of the School was formed in October, 1881, with a system of instruction to determine upon and the material to provide to carry it out, with an entirely new set of students to organize and divide into classes according to their knowledge and capacities, and to furnish with the necessary materials and apparatus, and with the class-rooms to rearrange and accommodations to provide for the unexpected number of applicants; the results are gratifying.

The main feature of the School has been the teaching of such drawing as would be useful in the workshop and applicable to construction as well as to ornamentation, and thus a large part of the instruction has been devoted to the geometrical principles of drawing, but the demonstration and application of these principles have always been made to conform with the practice of our best engineers and architects, while proper manipulation and correct technicalities have been rigidly enforced; so that the student would learn how to properly use his hands and his instruments, how to give clearness and beauty to his work, and at the same time obtain a knowledge of geometrical forms

and their projections, intersections and developments, and finally, learn to make working drawings of machine or architectural constructions.

In this course, the use of copies has been almost entirely avoided, the student being required to make his drawings accurately to scale, either from free-hand sketches, or from the drawing on the blackboard by the preceptor, who spends part of his time there and part with the student in giving individual instruction and criticism. Importance is attached to the free-hand sketches of the student, and the value of this accomplishment is always kept in view. The class of exclusively free-hand drawing has been small, but the progress has been very satisfactory.

The School is divided into:

A Junior Class, under Mr. Carl Barth, who teaches the use and care of instruments, graphical plane geometry, including the conic sections and spirals, and simple projections.

An Intermediate Class, under Mr. Victor Angerer, who teaches projections, intersections and developments, and elementary descriptive geometry, using the third angle exclusively and avoiding the use of the ground line of the text books, except where necessary, and then emphasizing the fact that it is not used in working drawings. He alternates the making of working drawings of simple details with this theoretical teaching.

A Senior Mechanical Class, which I teach personally, advancing further into descriptive geometry, together with gearing and shapes and proportions of teeth, making diagrams of mechanical movements, drawing to scale, marking dimensions in a proper manner, cross-hatching, coloring, shade lining and all the conventionalities of good draughting. During the last term this class made complete working drawings of a horizontal engine, in which they took great interest, so much so that each season I shall take some standard machine as a study for the class.

An Architectural Class, under Mr. Wm. L. Price, who practically applies the principles taught in the Junior and Intermediate Classes to the making of architectural drawings. Mr. Price also teaches the Free-hand Class.

During the winter term of the season there were 120 students, divided between the Junior, Intermediate and Senior Mechanical Classes, 20 in the Architectural Class and 26 in the Free-hand Class, making a total of 166.

During the spring term there were 95 students divided between the

Junior, Intermediate and Senior Mechanical Classes, 17 in the Architectural and 11 in the Free-hand Classes, making a total of 123.

The attendance has been fair, although the proportion of absentees was greater than would be expected.

The discipline has been good and the interest of the students in their work has kept up remarkably well. Some little trouble has been experienced from the independent spirit of American youths, who occasionally differ from their preceptors as to the adaptation of certain exercises to their own particular requirements.

Another threatened trouble has been a too large congregation of students in the Library. I would suggest the withdrawal of the privilege of the Library on School evenings.

Twelve Free Scholarships from the B. H. Bartol Fund have been at our disposal during the season, nine of which were awarded at the end of the Spring Term, and the remaining three are now awarded, with the approval of the Board of Managers, to the following students for their regularity in attendance, industry and interest in their studies, and the progress shown by their work, namely, to

Joseph Leibsch, of the Free Hand Class, and to Fred. Schroeder and Martin Marshall, of the Junior Class, who, on application to the Actuary of the Institute at the beginning of the next term, October 2d, will receive their tickets.

The following students deserve honorable mention for their regularity, industry and progress:

SENIOR MECHANICAL CLASS.

Willis H. Groat,	J. V. Hamilton,
Chas. S. Krebs,	A. M. Hahn,
H. Frank Lennig,	G. W. Bradley,
Joseph Weiss,	W. J. Bradley,
Conrad Shaul,	R. W. Ferguson,
Reinhold E. Kuehln,	G. Whitaker,
W. P. Dallett,	John P. Casey.

INTERMEDIATE CLASS.

A. R. Ridgely,	Geo. D. Holt,
J. F. Braun,	Chas. S. Butz,
R. W. Champlain,	John Fauser,
Rudolph Boericke,	J. McCoy,
Thos. M. Seeds, Jr.,	Clark Dill.

JUNIOR CLASS.

Martin Marshall,	John W. Atkins,
Fred. Schroeder,	A. C. Gilbert,

Lewis Mayall.

ARCHITECTURAL CLASS.

H. E. Grau,	Wm. S. Glein,
Horace King,	Peter Motley,
Wm. S. Yerkes,	John O'Neill.

FREE HAND CLASS.

Joseph Liebsch,	John J. Breitlinger,
Richard Binder	Harry Miller,
Elwood C. Hall,	Geo. H. Merchant.

The drawings, which are exhibited for inspection, are average specimens of the work done. Some are good, some indifferent, and some decidedly bad. Much of the bad work is in consequence of the very poor instruments used by a large proportion of the students, and does not form a true index of their understanding and capabilities.

In conclusion, I wish to thank the preceptors, who have assisted me in the school, for their zeal and fidelity; also, the Committee on Instruction, Curators and Board of Managers for their willingness, promptness and liberality in providing additional accommodations, and the officers of the Institute for their hearty co-operation and assistance.

WM. H. THORNE.

May 18, 1882.

Mr. Coleman Sellers, Rev. Dr. H. J. Morton and Coleman Sellers, Jr., were then successively introduced by the President, and delivered brief addresses, which were well received.

The exercises throughout were most interesting, and the expressions of gratification by members present at the flourishing condition of the school and the progress of the pupils, were very general. W.

Franklin Institute.

HALL OF THE INSTITUTE, April 26, 1882.

Pursuant to action taken at the stated meeting of April 19th, an adjourned meeting of the Institute was held this evening at the usual hour, the President, Mr. Wm. P. Tatham, presiding. There were

present 45 members and 5 visitors. The minutes of the preceding meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and announced that at the last meeting of the Board 17 persons had been elected members of the Institute. He also reported, under instructions received, the following resolutions passed by the Board, to wit: "On motion of Mr. Chas. H. Banes, Chairman of Committee on Exhibitions, it was

"*Resolved*, That, in consequence of the failure to find suitable accommodations in a central locality for the purpose of a public exhibition of arts and manufactures, and of the inability of the Institute, through lack of funds, to erect a temporary structure, we deem it advisable to abandon the project of a general exhibition for the current year.

"*Resolved*, That this inability, through want of proper space accommodations to meet the public demands of the Institute, and the limited quarters now occupied by its valuable library and scientific apparatus, together with the insecure condition of the present building, from liability to destruction by fire, should prompt to further and more determined effort to obtain subscriptions for a new structure.

"*Resolved*, That, in view of the public spirit manifested by the Franklin Institute, through its prompt and valuable assistance in scientific matters of public interest, through its free lectures delivered by eminent scientists and specialists, and its large and accessible reference library, an earnest appeal be made to the citizens of Philadelphia for funds to greatly enlarge its facilities for usefulness."

An additional resolution was reported, advising certain members who had made application on April 20, 1881, to be constituted the Mechanical Engineering Section of the Franklin Institute, that, by reason of their failure to organize and report their organization to the Board within the time specified in the by-laws, the section had become extinct.

Mr. Robert Grimshaw then read the first paper of the evening, the subject being "The Influence of Pulley Diameter on the Driving Power of Belts." An abstract of Mr. Grimshaw's remarks has been referred to the Committee on Publication.

Mr. G. Morgan Eldridge read a description of his newly devised "Thermograph," an apparatus for making a continuous graphical

record of the variations of temperature. The paper, with suitable illustrations, is published in the JOURNAL for June.

In his monthly report, the Secretary, after reading the reports of the Chemical and Phonetic Short-hand Sections, announced that Mr. J. D. Rice, member of the Institute, had presented for deposit among the models of the Institute, at the request of Judge Hare, the lightning-rod points, with a section of the rod, which had been erected by Prof. Robert Hare, forty or fifty years ago, to protect his dwelling-house, which formerly stood upon the site now occupied by the new Post-office, and which was demolished some years ago to make way for the latter. This interesting relic is thus described by Prof. Hare in the edition of his Chemistry published in 1840, viz.: "I have surmounted the lightning rod, by which my mansion is protected, by 17 copper wires, pointed at one end and at the other soldered into a hole drilled in the rod, which is constructed of iron. The junction is surrounded by a globe of zinc of about two inches in diameter, above which the wires extend divergingly. The copper wires, by their association with zinc, are protected from oxidation; while their greater fusibility, as compared with the platinum point usually employed, is compensated by their number. The rod thus mounted rises about 10 feet above the apex of the roof, to the copper covering of which its lower end is soldered. The copper covering has an ample metallic connection with the pipe for carrying off the rain, and this pipe with those of the public water works, all the joints being made with screws or solder. By these means a most ample means of communication with the earth is obtained. Analogous means should be employed in the case of all lightning rods in situations where access can be had to a similar ramification of metallic pipes." After reading the above extract, the Secretary noted as an interesting fact, that the method employed at that early day by Prof. Hare corresponds in every essential particular with the best practice in vogue to-day for protecting buildings from injury by lightning. The protective influence exerted by the union of the copper points with the zinc globe, as noted by Prof. Hare, was alluded to as a fact of special interest, the condition of the points after nearly half a century's exposure to atmospheric influences showing a remarkable state of preservation, being now almost as sharp as when the rod was first put up. Accompanying the

relic, Mr. Rice presented for comparison a modern copper rod—a twisted cable of a number of copper wires without points, with the ends frayed out in brush-like form.

The Secretary read also a long communication from Mr. D. T. Lawson, of Wellsville, Ohio, describing the details of certain experiments which he had caused to be made to demonstrate the correctness of his views, that a steam boiler can be exploded by the sudden removal of a considerable volume of steam from the boiler, causing the sudden bursting into steam of the superheated water; and describing, also, a preventive which he had devised to guard against this form of danger, consisting of an arched perforated diaphragm fixed horizontally near the water-line inside of the boiler, designed to regulate the rapidity of the abstraction of steam from the boiler.

Among the mechanical and technical novelties exhibited, the following are of sufficient importance to warrant special mention, viz.: Bailey's astral lantern, an ingenious device for showing maps and furnishing a "directory" of the heavens; an "accelerating" shot, invented by Thomas Shaw; Jenks' duplex injector; a full suite of products of asbestos from the H. W. Johns Manufacturing Company, and of mineral wool from the U. S. Mineral Wool Company; the Perret furnace for burning refuse fuel, shown by Ostheimer Bros.; Mestern's water-spray ventilating apparatus; a driving-wheel for sewing machines, turning on steel ball bearings with greatly reduced friction, exhibited by the Hartford Sewing Machine Company; Arnold's steaming apparatus for cooking; a minute egg glass, with an alarm bell attachment, for use in boiling eggs, and Herren's milk tester. This has a glass disk, with sections colored to represent different qualities of milk. A drop of the milk to be tested is pressed under the clear centre space of the glass disk into a thin film, and its quality judged by comparison with the standard shades of color on the edges of the disk. The two latter inventions were exhibited by Wm. M. McAllister.

Mr. William B. Cooper then followed with a description of a new apparatus for increasing the dynamic effect of the pulsations of diaphragms, etc., which he termed the "phonodynamograph." A model of the apparatus was shown at the close of the meeting, and an abstract of the speaker's remarks appears in the JOURNAL.

The meeting thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*

HALL OF THE INSTITUTE, May 17, 1882.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 125 members and 17 visitors.

On the reading of the minutes of the meeting of April 26th, the Actuary called attention to the fact that the number of members reported as having been elected at the previous meeting of the Board of Managers should be 17, instead of 21, as read; and with this correction the minutes were approved.

The Actuary submitted the minutes of the Board of Managers for May, and reported that at that meeting 21 persons had been elected members.

Mr. C. Colné, the Secretary of the American branch of the Interoceanic Canal Company, read an interesting paper giving important details concerning the engineering features and commercial aspects of the De Lesseps enterprise at Panama, together with a statement of the present condition of the work on the Isthmus. He deprecated the opposition to the enterprise that had been manifested in some of the daily journals, alleging that this hostility emanated from parties interested in rival projects and asserting that the company would demonstrate that it was not in any sense anti-American, but was, on the contrary, deserving of the full sympathy and support of the American people.

Remarks upon the paper were made by Messrs. Hector Orr and J. W. Nystrom.

The paper has been referred to the Committee on Publication.

At the close of the discussion on the subject, on the motion of Mr. C. Chabot, the thanks of the meeting were tendered to Mr. Colné for his interesting and valuable communication.

Mr. George S. Strong next described his improved feed-water heater and purifier and filter, illustrating the same with the aid of the lantern, and by a specimen of the heater. An abstract of the description has been prepared for the JOURNAL.

Mr. Louis S. Spellier followed with a paper on Electric Clocks and Time Telegraphs, describing certain improvements and simplifications in such apparatus, which he had devised. The paper was well illustrated, and has been referred to the Committee on Publication.

Mr. Wm. B. Cooper then made some remarks, explaining more fully than he had been prepared to do at the previous meeting, his

method of increasing the dynamic effect of the pulsations of diaphragms. Mr. Cooper's remarks have likewise been referred for publication.

The Secretary's report, which was abbreviated on account of the lateness of the hour, included the report of the Chemical Section and a brief description of mechanical and technical novelties which were on exhibition. Of these the following are worthy of special mention: A very complete and representative exhibit of graphite and products manufactured therefrom, made by the Joseph Dixon Crucible Company of Jersey City, N. J.

A number of improved tubular lanterns shown by Mr. J. H. Irwin, of Morton, Delaware co., Pa.

Cooke's Illuminating Oiler, an oiler and lantern combined in compact form; a very convenient device for using in the dark in and about machinery, as the lamp is so arranged that it throws its rays directly across the nozzle of the oiler to the place desired. Shown by the H. B. Smith Manufacturing Co., Philadelphia.

A number of fine specimens of phototypes, shown by Mr. F. Gutekunst, of Philadelphia, and a fire escape ladder shown by Wm. G. Selzer & Co., Philadelphia.

Prof. E. J. Houston then addressed the meeting at some length, calling attention to the dangerous character of the sewage emptied into the Schuylkill river near the eastern end of Girard avenue bridge, close to the Spring Garden Water Works, and within less than a mile of the Fairmount Works.

After remarks by Mr. W. B. Cooper, C. Chabot and G. Morgan Eldridge, it was, on motion, resolved, that the President be requested to appoint a committee to give expression to the views of the Franklin Institute concerning the pollution of the waters of the Schuylkill from the entrance of sewage near the eastern end of the Girard avenue bridge, and to report their conclusions, with such recommendations as they felt called on to make, to the next meeting of the Institute.

Tre President, in pursuance of the above resolution, named the following committee, viz.: Prof. E. J. Houston (chairman), Frederick Graff and Reuben Haines.

The meeting was then, on motion, adjourned.

WILLIAM H. WAHL, *Secretary.*

ERRATUM.—Chase. Radio-dynamics, etc., page 437, line 4 from end of article, for $961^{\cdot\prime\prime}83$, read $961^{\cdot\prime\prime}83$.